COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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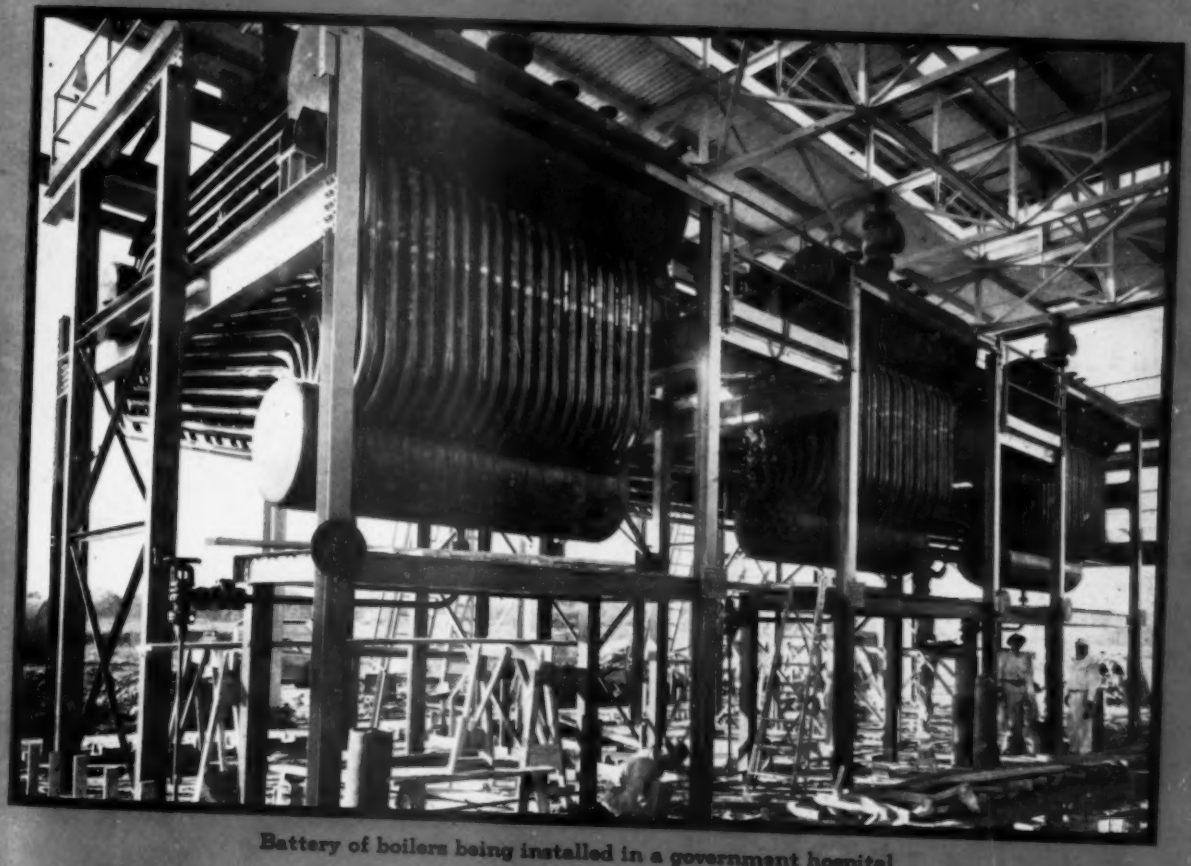


Battery of boilers being installed in a government hospital

Steam Jet Ejectors—Their Selection and Operation ▶

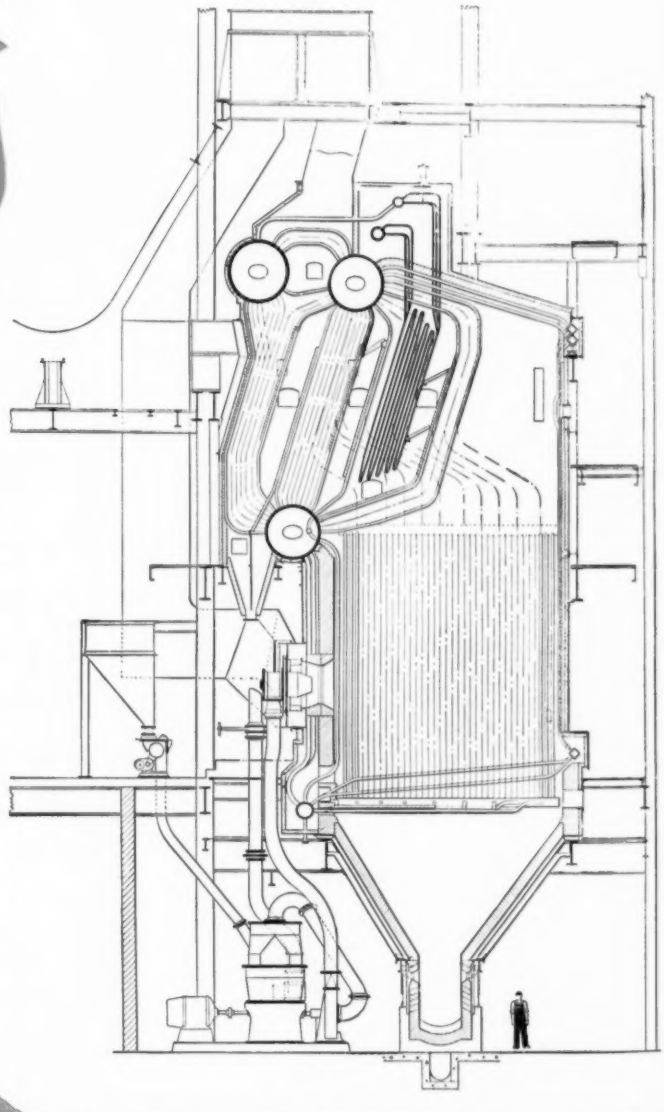
How the Navy Trains Boiler Operators ▶

Progress in Steam Generation ▶

MONTVILLE

Repeats

WITH ANOTHER BIG C-E UNIT



Two C-E Steam Generating Units, each designed for a pressure of 725 psi, a total steam temperature of 825 F and a maximum capacity of 130,000 lb of steam per hr, were placed in service in 1937 by the Connecticut Light and Power Company at its Montville Station.

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A-930

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C-E PRODUCTS include all types of boilers, furnaces, pulverized fuel systems and stokers; also superheaters, economizers and air heaters.

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME 17 **NUMBER 7**

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JANUARY 1946

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Editorial

An Absence of Engineers

Looking back over the makeup of the numerous boards created by the Government during the war to handle labor disputes and the more recent fact-finding committees appointed to deal with the current epidemic of strikes, one finds almost invariably, that the members selected to represent the public's interest have been drawn from the legal profession or college faculties. The absence of engineers is marked. Yet it would seem that an engineering approach to such problems might be most helpful.

The engineering profession has long been criticized, from within, for its failure, individually and collectively, to take a more active part in affairs of public concern. While it has achieved high prestige and recognition from the Government and the general public in the technical field, and this was further enhanced by its contribution to the war effort, engineers are usually passed over when the broader social or economic problems come up for consideration.

It may be that, on the subject of labor relations, Government officials are inclined to regard engineers as imbued with the management viewpoint; but surely there are enough unattached engineers of recognized independence from among whom selections could be made to insure impartial consideration. It is believed that the public's interest would be as safe in their hands as in the hands of lawyers and professors, and that the analytical approach, characteristic of engineering training, would offer a constructive solution in many cases.

Educational Facilities Taxed

Indications are that schools and colleges throughout the country will begin the second semester with enrollments taxing their capacity. This is due in part to the many returning veterans exercising their educational privileges under the G.I. Bill of Rights, and in part to the pent-up demand for higher education among the younger folks, including girls, which could not be satisfied during the war or which was deferred by opportunities for highly remunerative employment without experience during that period. Also, with the return of veterans ahead of schedule, many who wish to continue their education are finding it difficult to find accommodations in their chosen courses.

The situation is likely to become still more acute before the fall semester when most of the veterans now overseas will have returned to this country.

It is unfortunate that the present unsettled conditions have sprung up, delaying a return to anticipated peacetime production and its dependent activities, which could have absorbed the services of those awaiting favorable action on their enrollment applications.

STEAM-JET EJECTORS— Their Selection and Operation

The steam-jet ejector is a vacuum pump used to evacuate many types of equipment. Its application to condensing-type steam turbines is discussed in this article. It is universally used as the most economical form of vacuum pump for removing the air and entrained vapor from condensers serving steam turbines because of its simple, compact arrangement and the absence of moving parts.

By J. C. CROWNOVER,
Engine and Condenser Dept.,
Allis-Chalmers Mfg. Company

CONDENSERS are used to condense the steam exhausted from steam turbines, to produce a vacuum, and maintain the lowest economical exhaust back pressure. The steam condenses when contacting the cold condensing surfaces thus reducing the pressure below the surrounding atmosphere. This differential pressure induces atmospheric air leakage through glands, joints, etc. Other noncondensable gases may also enter with the steam from the boilers, but this quantity is negligible with modern feedwater treating equipment. The total amount of noncondensable gases discharged from the after-condenser and measured by an air meter is generally spoken of as air leakage. Noncondensable gases are poor conductors of heat and if not removed will accumulate to blanket the condensing surfaces, thereby preventing the steam from condensing and thus decreasing the amount of vacuum obtainable or preventing it altogether. It is impossible to maintain an absolutely tight system; hence, some means must be provided for removing any air that may enter the system. For this purpose steam-jet ejectors are commonly employed.

Proper application is based upon consideration of the actual performance conditions that are to be met and a thorough understanding of the performance characteristics of the various types of ejectors. The type of equipment to be evacuated, including its size, amount of steam to be condensed and the various operating conditions to be expected, must first be known. Then in order to select and design the proper ejector, it is necessary to know the desired operating range of pressure in the equipment to be evacuated, the amount of air leakage into the system, the quantity and maximum temperature of circulating water to be used in the inter- and after-condensers, the motive steam pressure and temperature available, and the back pressure against which the ejector is to operate.

The operating pressure within the system to be evacuated is generally designated as inches Hg absolute pressure, because this value is used in calculating the performance characteristics of vacuum equipment. This pressure is measured directly by an absolute pressure gage or indirectly by a vacuum gage of the mercury column or U-tube type and a barometer. The vacuum gage indicates the vacuum as inches of mercury below the surrounding atmospheric pressure. The absolute pressure is determined by subtracting the vacuum reading from the barometric pressure at the same elevation. If it is desired to express the vacuum in inches of mercury, referred to a 30-in. barometer, it is necessary to subtract the absolute pressure from 30 inches Hg absolute.

Air leakage is an uncertain quantity and its determination for design use is based upon data accumulated from experience with similar equipment. This quantity expressed in pounds per hour is used to calculate the capacity performance characteristic of the ejector. Air leakage expressed in cubic feet per minute of free dry atmospheric air at 70 F and 29.92 in. Hg absolute pressure should be multiplied by 4.5 to convert it into pounds per hour. In other words, one cubic foot per minute of air flow at the preceding temperature and pressure is equivalent to 4.5 lb per hr air flow.

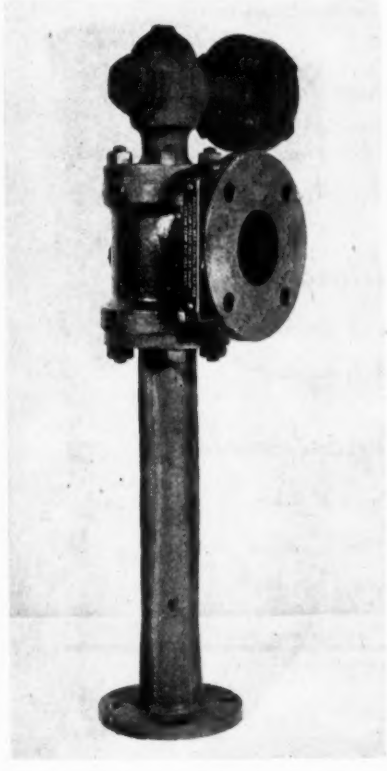

Fig. 1—Single-stage steam-jet ejector

The quantity and temperature of the circulating water flowing through the inter- and after-condensers of condensing-type ejectors are determined by the expected operating cycle. This water is usually condensate with temperature and quantity fixed by the condenser design. If raw water is used, its maximum temperature should be known. Usually this is the same as the circulating water to the main condensing equipment.

The motive steam is generally taken from the main steam supply to the turbine or engine. This steam may be used directly by the ejector or, if the initial pressure is too high for the ejector design, it may be reduced through orifices and flow control valves to the proper ejector design pressure. If a low-pressure steam supply is available, it may be desirable to use this directly by the ejector rather than to throttle down from a very high pressure. The minimum and maximum pressure and temperature of the steam supply must be known to properly design the ejector nozzles. Superheat at the ejectors is desirable since it assures drier steam to prevent erosion of parts and provides for stable performance.

Back pressure against which ejectors operate is generally atmospheric pressure. If higher than atmospheric, the maximum pressure to be encountered must be known so the ejector can be designed to discharge against it by increasing the steam consumption.

General Description

The steam jet ejector operates on a kinetic principle utilizing the momentum of the motive steam, the energy of which is converted by expansion through a nozzle, into a high velocity jet, which entrains and accelerates the medium in the suction chamber. The mixture is directed into a diffuser designed to provide a self-compression of the high velocity mixture to a static pressure greater than exists at the ejector suction. Thus a vacuum is produced and maintained in the closed system from which the ejector takes suction.

A standard basic assembly consists of the following:

Steam chest	cast steel
Strainer	stainless steel
Nozzle	stainless steel
Suction chamber	cast iron
Diffuser	bronze
Diffuser discharge tail piece	cast iron or bronze

This ejector may discharge into a condenser of the direct or indirect type where its motive steam is condensed. The standard materials of these condensers consist of the following:

Condenser bodies	cast iron or steel plate
Surface condenser tubes (condensate flow through tubes)	Muntz or inhibited Admiralty metal. These tubes are expanded at both ends into the tube sheets.

Special tube materials may be required if raw water is used instead of condensate. The material required will depend upon the corrosive characteristics of the water.

Steam-jet ejectors are built upon a thorough background of engineering development, testing and operating experience. Application to any specific job is based upon complete consideration of the actual performance conditions to be encountered and each ejector is given a shop test to closely simulate these operating conditions prior to its final installation. Stable and dependable performance is assured regardless of the number of stages used. Ejectors of the multiple-stage type are capable of maintaining higher vacuum and require less steam than the single-stage type.

Ejectors may be of the condensing or noncondensing type. The steam consumption of single-stage ejectors is the same whether they be of the condensing or noncondensing type. Steam consumption of multiple-stage ejectors can be decreased by using an inter-condenser between stages to condense the motive steam. Condensers may be of the direct or indirect type. The indirect surface type is recommended for most power plant service. Condensate from the main condenser is used as the condensing water to recover practically all of the heat content of the motive steam, and its condensate is reclaimed by draining it back to the main condenser through a loop seal or trap.

A description of the various types of ejectors and factors which determine the proper application of each to specific service conditions follows.

The single-stage ejector (Fig. 1) is a basic assembly designed to operate at a suction pressure below atmospheric and compress in one stage directly to a discharge pressure of one atmosphere or more. These ejectors may be used for suction pressures down to $3^1/_2$ in. Hg absolute and to serve condensers of small capacity. Normally, they are designed for motive steam pressures from 70 to 400 psig.

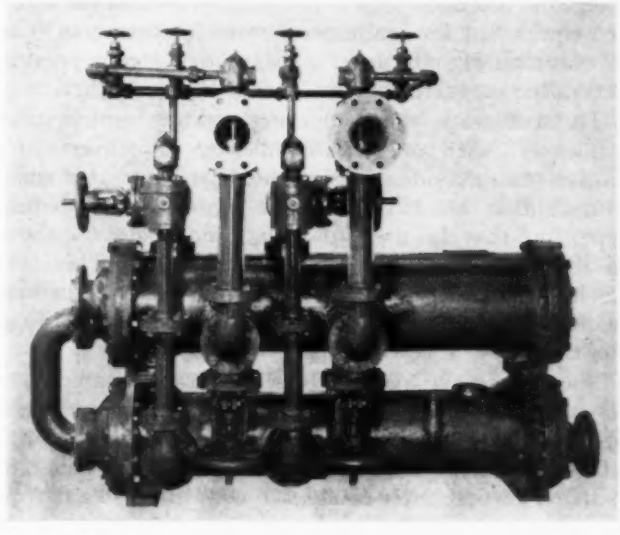

Fig. 2—Two-stage twin-element steam-jet ejector with separate inter- and after-surface condensers

This ejector may discharge directly to atmosphere or to an after-condenser which condenses the motive steam. The after-condenser will not improve single-stage ejector efficiency, but it is used to conserve the heat and condensate of the motive steam or to eliminate the nuisance of discharged vapor.

The priming ejector is a single-stage ejector, usually of the noncondensing type, having large air removal capacity at relatively low vacuum. It is used to assist the normal ejector equipment in the initial evacuation of vacuum systems to provide for quick starting. Economy is not a factor, because this unit is operated for a short time only during the initial starting period. In addition to evacuating the vacuum system, this type of ejector may also be designed to prime pumps and hydraulic systems.

The gland-seal ejector is of the single-stage type. It is used to maintain a low vacuum of a few inches of water at the gland seals of steam turbines, valves, etc., to prevent leakage of steam to atmosphere. Pre-condensers can be used to condense the gland steam before entering the ejector suction chamber, thereby reducing the ejector load. After-condensers are used to condense the steam discharged from the ejector. Steam at pressures down to 10 psig may be used because the steam consumption of such ejectors is low and, if designed for high-pressure steam, the nozzle throat becomes very small.

The multiple-stage ejector consists of two or more basic assemblies arranged in series. Dividing the total compression among several stages is more efficient than completing it all in one stage. The first stage takes suction at the highest vacuum desired and the final stage discharges to atmospheric pressure or greater. By utilizing an inter-condenser between stages to condense the motive steam from the ejector nozzles, the weight and volume of vapor to be pumped by the next stage are reduced, thereby reducing the size and overall steam consumption.

The two-stage condensing type ejector (Fig. 2) with inter- and after-condensers is normally used as the standard equipment for condenser service for pressures down to one inch Hg absolute. The motive steam pressure generally ranges from about 70 to 350 psig.

The two-stage noncondensing ejector, minus inter-condenser, with an after-condenser to conserve the motive steam condensate and heat has a greater steam consumption than the normal two-stage condensing type, but may be used to replace single-stage ejectors to serve condensers of smaller capacities. This type has higher capacity and less steam consumption than the single-stage type and has the same simple piping arrangement.

The three-stage ejector is used for pressures down to 0.5 in. Hg absolute or to replace two-stage equipment where reduced steam consumption is desirable. Two inter-condensers and one after-condenser are generally used. The first inter-condenser condenses steam from the first-stage ejector and the second condenses the steam from the second stage. The motive steam pressure ranges from about 70 to 350 psig.

Raw water may be used where no conservation of heat is desired or for special starting arrangement of standard equipment where the condensate quantity is insufficient or its temperature too high. Reduced temperature of circulating water flow through the inter-condensers will increase the overload capacity of multiple-stage condensing-type ejectors. This reduces the amount of saturated vapor entrained with the air to the following stage ejector suction, enabling it to produce a lower pressure in the inter-condenser because of its reduced load. The back pressure against which the previous stage must compress is thus reduced.

For a given steam consumption, the capacity of an ejector will be greater if designed for the higher pressure range due to the increased amount of available energy in the higher pressure steam. Consequently, the higher pressures are desirable.

The fundamental efficiency of an ejector decreases with increased pressures due to a lower entrainment efficiency at the higher velocities. But this reduced efficiency is negligible compared to the larger increase of available energy in the higher pressure steam. The maximum desirable steam pressure for an ejector is mainly determined by the size of the nozzle throat. Ejectors of low capacity and steam flow are designed for the lower motive steam pressures in order to provide for larger nozzle throats which are not so easily clogged with scale and dirt.

Higher or lower steam pressures than indicated may be used when desired. However, no economy will result from using pressures greater than those indicated. Large size priming ejectors are sometimes designed for full boiler main steam pressure to eliminate the use of steam-flow control valves.

Performance Characteristics

The final stage of a multiple-stage ejector unit is designed in accordance with the single-stage characteristics. The second stage of a two-stage condensing-type ejector is designed for about 4 to 6 in. Hg absolute

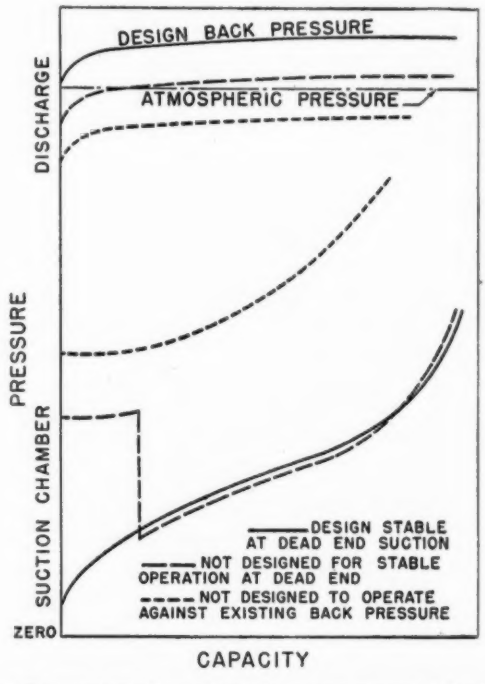

Fig. 3—Characteristics of single-stage steam-jet ejectors

pressure in the suction chamber and should be stable at a dead-end suction when compressing against existing back pressure. A definite quantity of steam flow is required to produce sufficient momentum in the diffuser throat to maintain proper vacuum in the suction chamber and to operate against the existing back pressure. If the back pressure is increased, it will be necessary to increase the momentum in the diffuser by increasing the steam consumption.

As shown in Fig. 3 the solid line curve represents the characteristic performance of a single-stage ejector designed for stable operation at a dead-end suction when compressing against atmospheric back pressure. As the capacity or load to the suction chamber increases, the pressure in the suction chamber increases and the ejector is able to operate against a back pressure considerably greater than atmospheric pressure. If the ejector were never expected to operate with reduced capacity near dead end, this design would represent a waste of steam

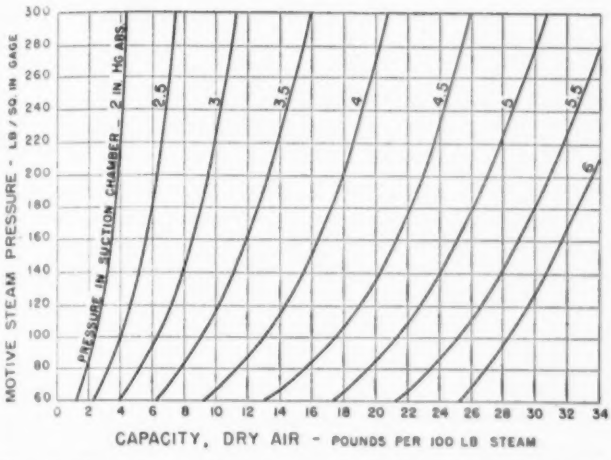

Fig. 4—Dry-air performance of single-stage steam-jet ejector

flow. However, most ejectors serving steam condensers may be required at times to operate with extremely small quantities of air leakage approaching the dead-end condition. Therefore, to assure stable performance throughout the entire capacity range, it is necessary to provide sufficient steam flow for stable dead-end operation.

The dashed line in Fig. 3 shows the effect of decreasing the steam flow for maximum economy, assuming that the minimum capacity will never be reduced below the point where the ejector can just operate against atmospheric pressure. Should the atmospheric pressure increase, or the capacity decrease, the ejector suction would break with a sudden increase of pressure in the suction chamber as shown by the curve. It would then be necessary to increase the steam flow by increasing the steam pressure or size of nozzle throat.

The dotted curve shows the performance of an ejector with a clogged nozzle or reduced steam pressure. This has insufficient steam flow to enable it to compress against the existing back pressure.

Once an ejector is operating properly against the existing atmospheric pressure, its capacity will be reduced along the high vacuum end of the characteristic capacity curve, if the steam pressure is increased. The capacity will increase at the low vacuum end of the curve. This characteristic and the cross-over point will depend upon the ejector design.

The dry air capacity of the second stage of a two-stage ejector can be approximated from the curves in Fig. 4. These curves are based upon the performance of an ejector designed for stable operation at dead-end suction when compressing against standard atmospheric back pressure. Due to the increased amount of available energy in the higher pressure steam, the capacity of this ejector will be greater if designed for the higher pressure steam as indicated by these curves.

The characteristic performance of a steam-jet ejector is such that its capacity will vary with the properties of the substance being handled. Its capacity will be less than the dry-air capacity if it is handling vapor or a mixture of air and vapor. The vapor capacity or air-vapor mixture capacity of an ejector may be approximated from the dry-air capacity by using the capacity factors shown in Fig. 5. This curve is recommended for use with the characteristic performance curve of an injector operating against a back pressure equal to or less than the initial design back pressure.

The pressure in the inter-condenser of a two-stage steam-jet ejector is determined by the second-stage ejector capacity, the circulating water temperature, and the performance characteristics of the inter-condenser.

The second-stage ejector of a two-stage condensing-type ejector unit will have a definite characteristic dry-air capacity curve as determined by a dry-air performance test. This curve shows the absolute pressure that may be maintained in its suction chamber with varying quantities of air. The pressure in the suction chamber increases with an increased quantity of air. If no steam were entering the inter-condenser, the pressure in the condenser would correspond exactly with the dry-air performance curve.

But in actual operation, steam from the equipment being evacuated, plus motive steam from the first-stage ejector, will enter the inter-condenser and the air will be saturated with vapor. Thus the second-stage ejector load will be increased. The colder the circulating water and the greater the inter-condenser surface, the greater the amount of vapor condensed and the closer the load to free dry air. But as the water temperature increases, less of the vapors condense and the load to the second-stage ejector increases with a corresponding increase of inter-condenser pressure. Thus with warm water, the air-handling capacity of the ejector at a definite pressure will be only a fraction of the dry-air capacity curve. Pressure in the inter-condenser will therefore depend upon the water temperature, the condenser design, and the ejector capacity.

Pressure in the inter-condenser may be conveniently approximated from the second-stage dry-air capacity, Fig. 4, as a function of inlet water temperature by using a curve similar to those in Fig. 6. Such a curve is based upon a circulating water temperature rise of 5 deg F and must be determined from actual test performance data taking into consideration the condenser loading and design.

To use such a curve, determine the second-stage dry-air capacity at a definite pressure, multiply it by the capacity factor at this pressure and the desired water temperature. The result will be the air-handling capacity of the inter-condenser and second-stage ejector

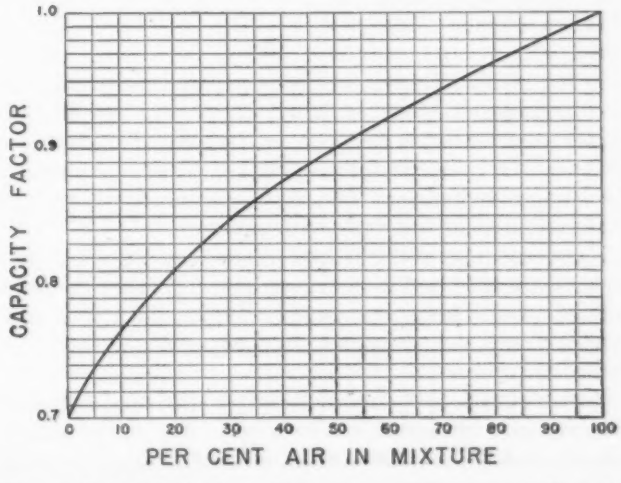

Fig. 5—Saturated air water-vapor mixture capacity of a steam-jet injector based upon a dry air capacity factor of 1

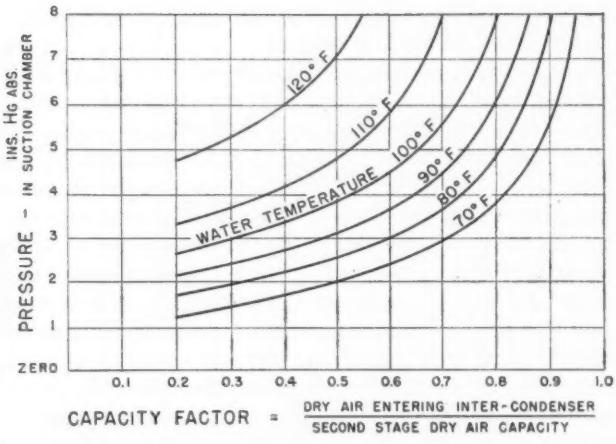

Fig. 6—Curves for approximating pressure in inter-condenser from the second-stage dry-air capacity

combination. The second-stage air-handling capacity may be determined for a series of pressures at different water temperatures, and plotted to show the pressure in the inter-condenser with varying amounts of air leakage and different circulating water temperatures.

These curves are used to determine the pressure against which the first-stage ejector must operate. As the water temperature or air leakage increases, the pressure in the inter-condenser will also increase. This means a corresponding increase of the first-stage ejector steam consumption which must be great enough to enable it to compress against the highest pressure expected in the inter-condenser.

First-Stage and Performance Characteristics of Complete Two-Stage Ejector Assembly

The first stage of a two-stage ejector takes suction from the main condenser and discharges into the inter-condenser. The characteristic performance of this ejector is based upon the same principles as the single stage. But this ejector is designed to discharge to a low back pressure, usually about 4 to 6 in. Hg absolute. The steam consumption will depend upon the size, or capacity, and the maximum back pressure against which it is designed to operate.

This ejector will handle the dry air entering the equipment being evacuated, plus the associated vapors. The quantity of vapor will generally be much greater than the quantity of air. The ejector design is based upon a saturated air-vapor mixture at $7^1/_2$ deg F depression. For convenience in approximating performance data, this mixture is assumed to consist of 30 per cent dry air plus 70 per cent saturated vapor at $7^1/_2$ deg F below the saturated temperature corresponding to the pressure in the suction chamber. The actual saturation factor is not constant and will vary with pressure.

The percentage of air in the mixture at different pressures is shown by the curve in Fig. 7. This is based upon Dalton's law. Air-vapor mixture data for other temperatures and pressures may be obtained from engineering handbooks.

Under actual operating conditions, the air leakage is reduced to a minimum. Therefore, the ejector will be handling very little air and practically all vapor. At a given operating pressure, assuming there is no air leakage, the ejector will handle all vapor, the quantity being equivalent to the ejector capacity at this pressure. This would correspond to zero temperature depression, which would never be expected in actual service. Normally, the actual temperature depression will be very low and difficult to measure as it will be much less than the ejector design basis of $7^1/_2$ deg F depression.

Fig. 8 has been plotted from data based upon Dalton's law to show the pounds of vapor per pound of dry air for various temperature depressions. These curves are also based upon 1, 2 and 3 in. Hg absolute, because the normal operating pressure in the first-stage ejector will range between 0.5 to 3.5 in. Hg absolute.

The capacity curve based upon $7^1/_2$ deg F depression is generally known from the ejector shop performance test. The performance at the actual operating condition of smaller temperature depression may be approximated from Fig. 5 or a similar curve showing capacity factor plotted against temperature depression at one inch Hg absolute pressure. It may be more convenient to use for the normal operating pressure range of the first-stage ejector.

It may also be found more convenient to base these calculations on a characteristic vapor capacity curve for certain installations. This curve can be obtained from tests by passing known increments of vapor into the suction chamber and plotting the increased suction pressure against the increased vapor capacity. It can be approximated by the manufacturer from calculations based upon the design of the ejector.

The characteristic design performance of a two-stage steam-jet ejector with a surface-type inter-condenser is shown by curves in Fig. 9. This performance is determined by the size and steam consumption of the first- and second-stage ejectors, the steam pressure and temperature, circulating water quantity and temperature, and the design of the inter-condenser.

The maximum back pressure against which the second-stage ejector may operate and pick up its vacuum to the characteristic suction curve is shown as well as its dry air capacity at various pressures in the suction chamber.

The pressure in the inter-condenser is shown for different temperatures of circulating water and air leakage. As the water temperature increases, the pressure in the inter-condenser also increases. The quantity of circulating water was constant and indicated a tempera-

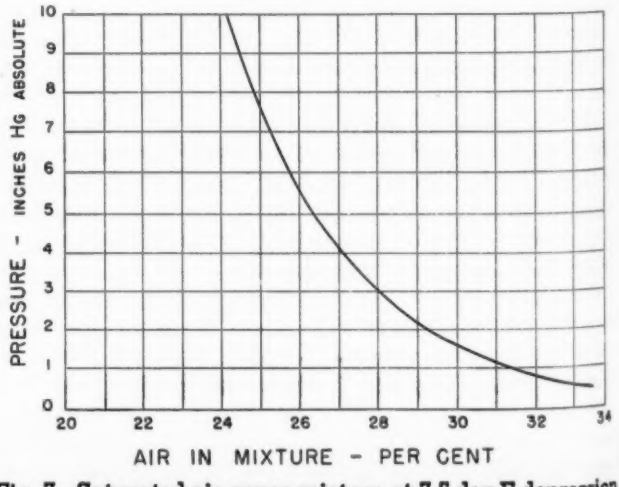

Fig. 7—Saturated air-vapor mixture at 7.5 deg F depression below the saturation temperature corresponding to the pressure

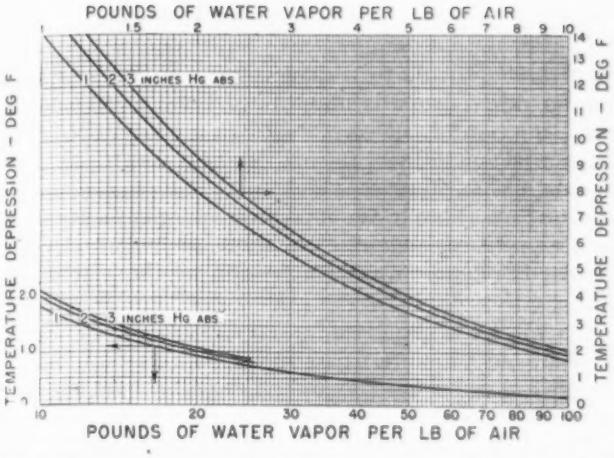
POUNDS OF WATER VAPOR PER LB OF AIR
TEMPERATURE DEPRESSION - DEG F
TEMPERATURE DEPRESSION - DEG F
1 1/2 3 INCHES Hg ABS
1 1/2 3 INCHES Hg ABS
POUNDS OF WATER VAPOR PER LB OF AIR

Fig. 8—Saturated air-water vapor mixture data based on Dalton's law

ture rise of approximately 2.5 deg F at the design capacity. Although the quantity of motive steam was constant, the temperature rise was not constant because it increased with the vapor capacity of the first stage at higher suction pressures.

Steam consumption of the first stage was sufficient to enable it to compress to a back pressure curve as shown. With an inter-condenser pressure equal to or less than this design back pressure, the first-stage suction pressure did not deviate one way or the other from its characteristic curve. But as the water temperature and air leakage increased sufficiently to increase the inter-condenser pressure above the first-stage design back-pressure curve, the first-stage suction broke and caused it to follow a new capacity curve at pressures above those of the characteristic curve.

The first-stage capacity curve was based upon the dry air being saturated with vapor at $7^1/_2$ deg F below the saturation temperature corresponding to the pressure in the first-stage suction chamber. The first stage was thus handling the dry air plus the associated vapor.

Circulating water flowing through the inter-condenser is usually condensate, the temperature of which corresponds to the pressure in the condenser. Thus as the pressure in the first-stage suction chamber increases, the temperature of the circulating water will increase. The solid line curve was plotted to show the performance of this ejector with condensate as the circulating water.

The performance curves illustrated by Fig. 9 are typical of a two-stage ejector designed for power plant service. The actual air leakage to be handled by the ejector will generally be much less than that shown by the ejector design. The actual operating pressure in the inter-condenser may also be considerably less than the design back pressure of the first-stage ejector. Actual operating compression ratio may thus be less than the design compression ratio, but this is desirable to provide for reserve capacity and assure stability for emergency service conditions.

Air Leakage and Steam-Jet Ejector Capacity

Steam-jet ejectors for surface condensers serving steam turbines are designed for an air leakage greater than the maximum air leakage expected in a completely tight system. The ejector capacity must be sufficient to handle this air leakage plus the associated vapors from the condenser. For convenience in selecting the most economical size ejector to serve condensers operating between 1 to 3.5 in. Hg absolute pressure, the design pressure has been established as one inch Hg absolute. The ejector capacity at this pressure is based upon the specified amount of air saturated with vapor at 71.5 F corresponding to a temperature depression of $7^1/_2$ deg F below the saturated steam temperature of 79 F at one inch Hg absolute pressure.

The most economical two-stage condensing type ejector capacity for various condenser capacities has been established as tabulated below, the air-vapor mixture based on 30 per cent air and 70 per cent vapor.

Steam condensed, maximum lb per hr	Dry-air leakage, lbs per hr	Design capacity at 1 in. Hg abs saturated air vapor mixture at 71.5 F in lb per hr	Steam consumption, lb per hr
5,000	9.9	33.0	132
10,000	11.3	37.5	150
15,000	11.9	39.8	159
20,000	12.6	42.0	168
25,000	13.5	45.0	180
30,000	14.4	48.0	192
35,000	15.1	50.3	201
40,000	15.8	52.5	210
45,000	16.4	54.8	219
50,000	17.1	57.0	228
75,000	20.2	67.5	270
100,000	22.5	75.0	300
150,000	29.2	97.5	390
250,000	38.2	127.5	510
350,000	45.0	150.0	600
450,000	51.8	172.5	690
600,000	60.8	202.5	810
.....	72.0	240.0	960

The steam consumption of three-stage condensing-type steam-jet ejectors designed for the above pressures and capacities will be 90 per cent of the tabulated steam consumption for two-stage ejectors.

The detrimental effect of air leakage in hindering heat transfer rate and increasing the condenser pressure is realized so that every precaution is taken to reduce it to a minimum. In a properly tightened system the air leakage should be less than shown in the tabulation. The leakage normally ranges from about 10 to 30 per cent of that shown.

Air leakage into a condensing bleeder turbine system is uncertain and may increase with a decrease in the turbine load. The rate of air leakage increase will depend to a great extent upon the number of feedwater heaters operating at pressures below the surrounding atmosphere at the various points in the operating load range. Since the pressure of bled steam varies with the throttle flow, at any given load a definite pressure will exist in each stage. These pressures are higher at increased loads and lower at decreased loads. Thus a varying amount of piping and fittings will be operating under vacuum at various turbine loads. As the load increases, the pressure in each heater increases. When the pressure increases to atmospheric or greater in each heater, the air leakage is reduced to zero into this heater system.

Effect of Ejector Capacity Upon Pressure at Inlet of a Surface Condenser

Air leakage into a surface condenser increases the operating pressure. The rate of pressure increase will depend upon the rate of air leakage, the operating conditions, the design characteristics of the condenser design, and the capacity of the ejector. Up to the design capacity of the standard ejector the effect of air leakage to increase the turbine exhaust pressure is small. The maximum increase of pressure may be approximated by knowing the characteristic performance of the ejector

equipment. This determination may be used to analyze the economic desirability of increasing ejector capacity to reduce the condenser operating pressure.

Up to an air leakage equivalent to the standard two-stage ejector design as tabulated, the ratio of air to steam entering the condenser is very small. The temperature depression and corresponding pressure tension are extremely small and could not be measured by present methods to indicate the presence of the air. But at the ejector the amount of air per pound of steam may be large enough to be indicated by temperature readings provided proper care has been taken in placing the thermometer for accurate measurement. The temperature depression if accurately measured will be the same as calculated by Dalton's law from the air leakage and the ejector capacity at the same pressure. The amount of air can be measured by an air meter and the ejector capacity may be approximated or determined from leakage. Under actual operation in the final installation, the actual temperature depression will be very small and difficult to measure because the normal air leakage into a properly maintained system will be only a small fraction of the ejector design air capacity. Also, the actual operating pressure may be greater than the ejector design pressure which further increases the saturation factor due to the increased vapor capacity at the higher pressure, assuming constant air leakage, and decreases the temperature depression at the ejector suction.

The ejector will handle its full capacity corresponding to whatever pressure exists in its suction chamber. If the air leakage is low the difference will consist of vapor. Thus with a low air leakage the amount of vapor or saturation will be much greater than that established for the ejector design. If the air leakage were reduced to zero the ejector would be handling its full vapor capacity

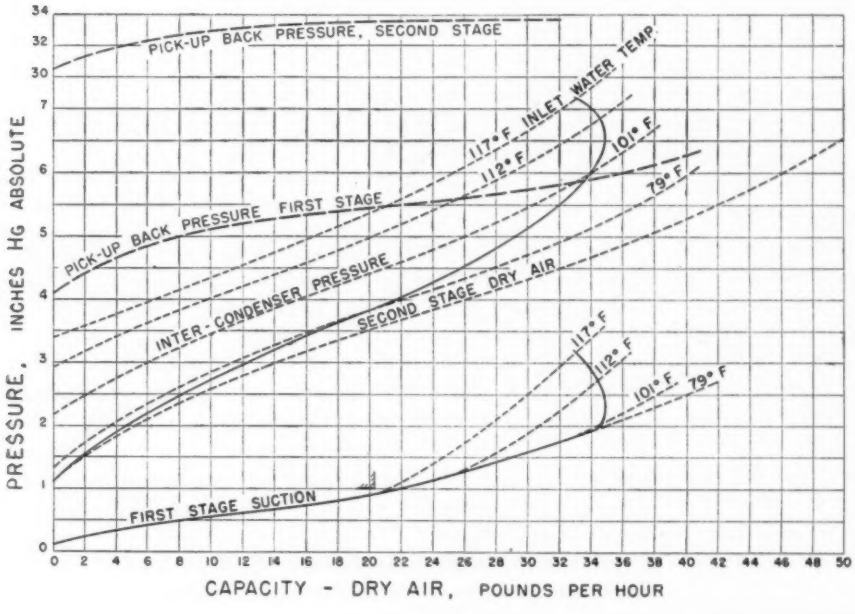

Fig. 9—Performance curves of two-stage steam-jet ejector with surface-type inter- and after-condensers, based on dry air saturated with vapor at 7.5 deg depression below the saturation temperature corresponding to pressure in the first-stage suction chamber

test. Knowing the ejector capacity the total pounds of vapor per pound of air may be determined. From this saturation factor at the operating pressure in the ejector suction chamber the equivalent temperature depression and pressure tension may be calculated. The pressure increase at the condenser inlet will not be as great as this pressure tension but for the average condenser installation will be approximately one-half or less than this figure depending upon the condenser design and operating conditions. Thus the pressure depression at the ejector suction may be used as an indication to determine the effect of the ejector capacity upon the condenser inlet pressure as its effect is reflected back through the condenser system. For approximating the maximum increase of condenser pressure due to ejector capacity it will be safe to use one-half of the calculated pressure tension as the maximum increase of condenser inlet pressure.

A standard two-stage ejector is designed and tested on the basis of an air-vapor mixture at $7\frac{1}{2}$ deg F depression as previously indicated. This is done for convenience of selecting and designing the most economical ejector having sufficient excess capacity to assure stable performance under unexpected conditions of excess air and the vapor temperature should correspond to the saturated steam temperature at the pressure measured in the ejector suction, assuming that the thermometer is not affected by heat conducted back from the hot steam chest or subject to other effects of radiation and heat conducted from the surrounding atmosphere. If this temperature is to be measured a thorough consideration of the proper location of the thermometer must be made to prevent false indications. A low temperature depression, if measured, would be very desirable because it indicates proper operation of the vacuum system indicating that air leakage is under control.

If there were no air leakage into a condenser system, no ejector would be required as there could be no pressure tension due to the air. In an actual condenser there is always air leakage and a pressure tension due to this air increasing the actual operating pressure. By increasing the ejector capacity the actual pressure tension may be reduced due to the increased vapor-handling capacity above the existing air leakage. Thus it would be possible to approach the ideal condition of no air leakage by reducing the pressure tension in the ejector suction. The maximum size and cost of ejector equipment would be determined by the improved water rate

resulting from the reduced turbine back pressure. The maximum condenser pressure reduction for different ejector capacities may be calculated as shown in order to make an analysis of the most economical size of ejector to serve a given steam turbine installation.

Minimum capacity recommended for a single-stage steam-jet ejector designed for priming surface condensers is shown in Fig. 8.

Determination of the ejector capacity required to evacuate a vacuum system within a certain length of time may be rather uncertain because of the possible variation of air leakage into different systems. Assuming that the system to be evacuated is properly maintained, the air leakage should be small. The steam consumption and time required to evacuate a given volume may be estimated from Fig. 10. This curve is intended for use down to 3 in. Hg absolute pressure in steam power plant surface condenser equipment. The ejector is designed for stable operation at a dead-end suction pressure of approximately 2 in. Hg absolute.

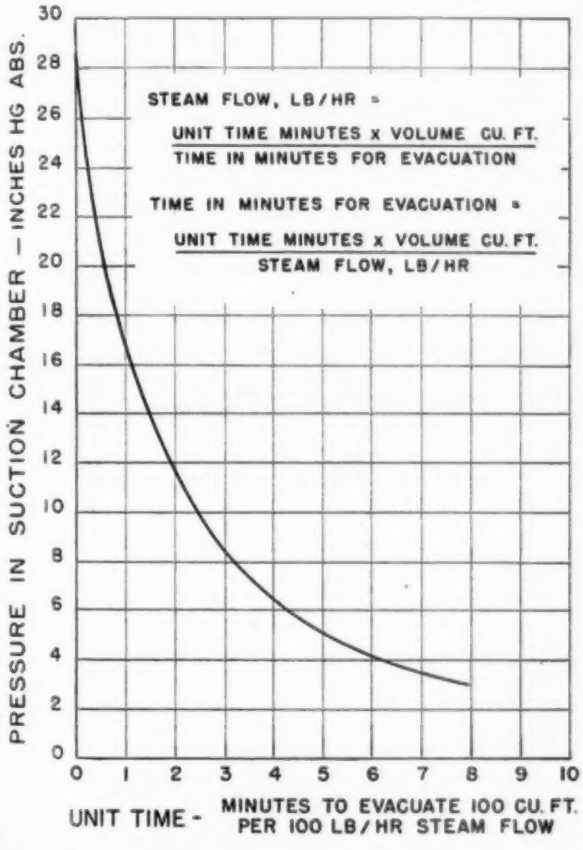

Fig. 10—Characteristic of single-stage ejector designed for priming surface condensers

Variation of Vacuum Due to Improper Operation of Steam-Jet Ejector Equipment

A motive steam flow different from the design steam consumption will affect the performance of steam-jet ejector equipment. A serious decrease of steam flow will be indicated by an unstable or a large drop in vacuum. Such a decrease may be caused by the following:

1. The motive steam supply may be different from the design conditions. A lower steam pressure or a higher superheat will decrease the amount of motive steam supplied. Seriously wet steam will cause a fluctuation of vacuum.

2. The steam strainer may be clogged and cause a reduced steam pressure at the nozzle. The strainer should be thoroughly cleaned.

3. The steam nozzle may be dirty or coated with scale. It may be cleaned by soaking in kerosene, blowing out with steam or air and scraping with a stick. The nozzle inlet radius and throat may be polished by passing a heavy string or strip of fine emery cloth through the throat and holding each end tightly, pulling it back and forth over the surfaces until well polished; but one should be careful not to enlarge the throat diameter since this would cause an uneconomical increase of steam flow.

4. The steam nozzle position may be critical and must be maintained by reassembling with the same thickness of gaskets and spacers as originally supplied.

Improper drainage of the condensate from the inter-condenser will also affect the performance of steam-jet ejector equipment. This will cause a fluctuation of vacuum. The accumulation of condensate in the lower portion of the condenser may be indicated by a noticeably cold lower portion of the shell and a hotter upper portion.

Improper drainage may be caused by dirty drain lines, air leakage on the ejector side of the inter-condenser drain loop seal or trap, a leaky circulating water tube or improperly operating drain traps.

A convenient method of checking the performance stability of the second stage of a two-stage condensing-type steam-jet ejector to determine its minimum operating steam pressure under actual installed conditions or to indicate a dirty nozzle is as follows:

It is assumed that the ejector is designed for stable performance at dead-end suction.

Install a vacuum gage on the suction chamber and a pressure gage on the steam chest. To get a true picture of ejector performance it is also necessary to know the steam temperature if considerable superheat is possible. This is not absolutely necessary for a rough check if the main supply steam condition is up to normal temperature and pressure, and if the piping from the main to the ejector is insulated and properly warmed.

With the ejector suction valve closed and the steam supply condition up to normal, throttle the second-stage steam pressure until a sudden drop in vacuum is noted or until the steam pressure is considerably below the ejector design pressure. Open the steam valve slowly and observe the vacuum. As the steam pressure is increased note the gradual increase of vacuum until it suddenly picks up to a maximum which should correspond to approximately one or two inches of mercury, absolute pressure. At the point of sudden increase in vacuum record the steam pressure and consider it as the minimum operating pressure with whatever superheat exists. A further increase of steam pressure will cause a gradual drop in vacuum or a decrease in pressure will cause a gradual increase of vacuum until the vacuum suddenly breaks. If these characteristics do not occur, especially if the vacuum does not pick up with an increase of steam pressure up to the design pressure, the ejector is not operating properly. It will then be necessary to remove the nozzle and strainer to remove thoroughly all dirt and scale.

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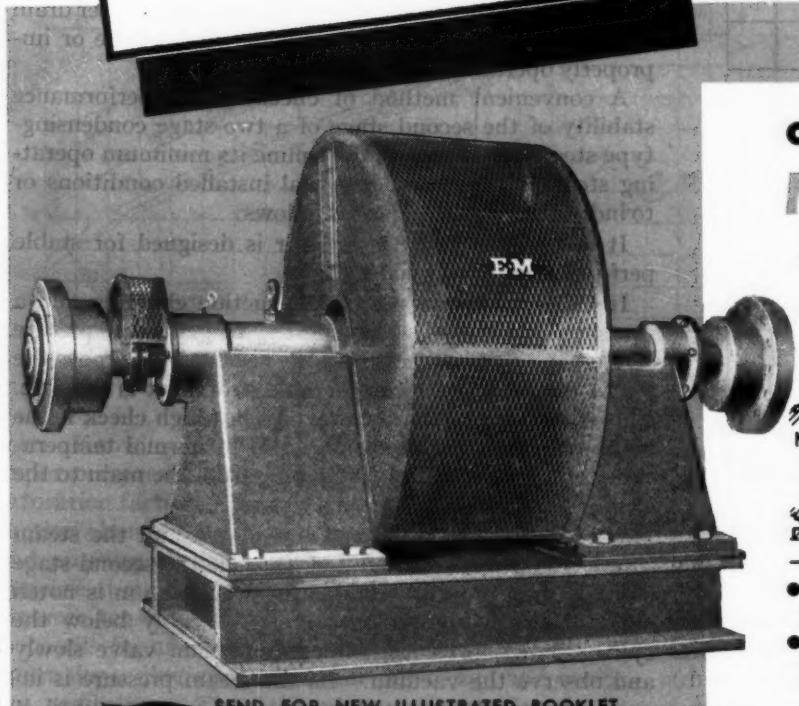

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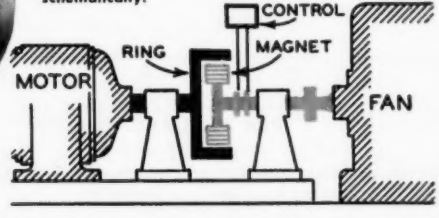

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Fig. 1—Students are required to maintain steam pressure constant and temperature within ±5 deg F through the entire range of firing rates

How the Navy Trains Boiler Operators

Faced with a tremendous expansion in the number of ships of all types and limited personnel trained in boiler operation, the Navy set up a training school at the Philadelphia Navy Yard where boys with no previous experience in this line were given six weeks' intensive instruction under conditions simulating those on shipboard. Following is a brief review of how this was accomplished.

NOW that the war is over, the story can be told of how the Navy intensively trained the men who manned the boilers, giving the ships incredible maneuverability in making their firepower effective.

At the Philadelphia Navy Yard, in a building which houses the Naval Training School (oil burning) at the Naval Boiler and Turbine Laboratory, the problem was to bring in the lads from the farms, garages, ice cream counters, etc., after they had six months or more at sea, and to teach them in six packed weeks how to handle high-pressure, high-temperature boilers, many equipped with combustion controls and other fireroom auxiliary equipment such as found on naval combatant and auxiliary ships.

The Navy Department, upon recommendation of the Bureau of Ships, established this school in response to an urgent need for trained water tenders to handle the operation of boiler installations of our tremendously expanded Navy. Moreover, Navy fireroom personnel in this war have been tossed aboard so many auxiliary ships, such as cargo vessels, troop transports, tankers, etc., in addition to combatant ships, that it was decided to teach them how to operate any system they might encounter. This meant including instruction on combustion control systems, inasmuch as many merchant ships are fitted with such systems.

Nearly 700 trainees were put through the course each six weeks and well over half of all the water tenders in the Navy completed the training during the war. Emphasis was placed on sending through the school the water tenders who had had no experience with modern high-pressure, high-temperature boiler installations.

At the head of the Naval Training School (oil burning) is Capt. C. A. Bonvillian, the Director of the Naval Boiler and Turbine Laboratory, and in direct charge is Lt. Comdr. P. R. Plant. Lieut. P. E. Fournier as Training Qfficer was responsible for developing the instructional material and particularly the many excellent training aids until he was later transferred to Okinawa. Capt. J. A. Hayes in charge of the Boiler Desk in the Bureau of Ships was instrumental in furnishing boilers

and necessary equipment for the establishment of the school. All have been highly enthusiastic about the new training program. They started something that is likely to build a more technically minded Navy in step with the latest modern devices. Also, they developed a method of imparting complicated technical information in a way that was neither dusty nor boring. Lectures and charts had to be used, of course, but movies, models and demonstrations along with the lectures, and particularly full-scale boiler operation were employed, so that the whole course of six weeks teemed with operating experience.

At the outset, the Navy realized that, to teach the principles of combustion, it would have to show the boys how such systems worked aboard ship. That meant buying the equipment and installing it in classrooms. To play fair between competitors, it meant installing those systems most likely to be found aboard any ship.

In the early part of the course the students were shown the various systems in a classroom. Since none of the classroom equipment is actually hooked up for steam, ingenuity went to bat to create "simulated operating conditions." That meant, where a certain condition would obtain with 500 psi steam pressure, instructors rigged up devices making the control systems work as if there were steam in the boilers. Incidentally, the tubing and other mechanisms were painted green, red, blue, yellow, black or white to make student understanding easier. Since there was no furnace in the classroom, a change in the orifice plate to get a small bleedoff attained the same result as a drop in pressure.

The students were shown that a decrease in the firing rate on the "saturated" side of the boiler, without a corresponding decrease on the superheater side, would result in an abnormal increase in the superheat temperature because the rate of steam generation had decreased. Thus the rate of steam flow through the superheater had also decreased but the firing rate remained the same. Consequently, they were told, with the same firing rate and a decreased flow, the temperature increases.

Fig. 2—Students firing a destroyer escort boiler

Later in the course the men really got down to cases. One part of the laboratory had become the simulated vitals of a destroyer escort, where teamwork between the firemen and the blower man is essential for optimum efficiency and the avoidance of smoke is a "must."

Combatant ship boilers are operated manually because the wide fluctuations in speed demanded in battle can call for power all the way from zero to full power and the auxiliary equipment to enable automatic combustion control to function under such extreme demands has not yet been perfected. On these, therefore, the Navy depends upon fully trained water tenders to operate individual oil burners, valves and blowers. It is nothing in naval practice to cut in a cold boiler and have high steam pressure in a few minutes.

A visitor to the school would have seen each man at his appointed station, many standing close together, but none speaking; just as if the destroyer escort were at sea in an emergency. A buzzer sounds and the men swing

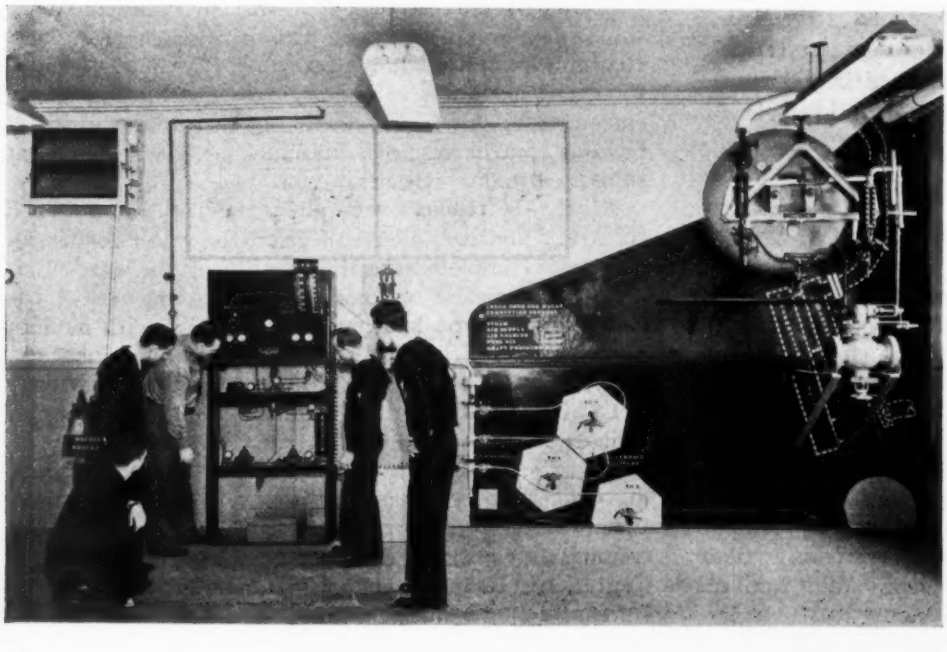

Fig. 3—A complete unit of Hagan automatic combustion control installed in the classroom and operated on air pressure to simulate closely a shipboard installation

into action as a team. On a panel at the end is seen in lights the words, "One Third." One lad decreases fuel flow by closing down on the micrometer valves; another reduces the air input; and a third swiftly spins a throttle governing steam flow to the turbines. Still watching the instrument dials which verify pressure and temperature, they throttle down the ship's speed and wait for the next order. It comes in a moment—"Standard Speed." Shifts of positions of levers, blowers and other devices follow as mere routine. Then "Full Speed" and the boilers appear to seethe with new steaming power. This is a ship that never moves; yet, watching these boys of the oil-burning school, one could well imagine that he was really down in the fireroom of a speeding destroyer escort.

Farther along in the laboratories is an even larger setup—a simulated boiler room of one of our modern battleships. Here another crew, with faces just as intent on dials and instruments, functions under constantly changing commands. Here again there is no need for "simulated conditions" because they actually have boilers under steam. Watching these lads perform, one is led to speculate on the havoc that could be wrought by a torpedo or a bomb penetrating to the fireroom of one of our battleships.

The capacity of the school was determined primarily by the number of men that could be accommodated in the school firerooms, operated on a 24-hr basis. There are six classroom subjects of seven three-hour sessions each—namely, boilers, combustion, operation, fuel oil and refractories, feedwater, and auxiliaries. Two series of fireroom drills and demonstrations are given: namely, six four-hour sessions in operation and maneuvering, and six two-hour sessions in combustion.

The boiler class is taught the elementary principles of steam generation and is progressively taken through the characteristics, construction and functions of the component parts of modern naval boilers. Procedures used in the maintenance of water-tube boilers, superheaters, economizers, safety valves, soot blowers and other boiler appliances are taught.

The combustion class, starting with principles of combustion, learns about the construction and operation of fuel oil atomizers and air registers, followed by principles of operation and, next, development of skill in maintaining fireroom instruments and automatic feedwater regulators and combustion controls.

The operation class delves into the reasons for superheat, and factors affecting this stepping-up of the temperature of steam. Students learn the preliminary steps in lighting off any boiler or in cold-lighting with no steam available; also procedures for cutting in, cutting out and securing naval boilers. They also learn methods of controlling superheat, causes of condensation in superheaters, methods of boiler control, safety precautions and localizing procedures to be used in event of damage to a boiler.

Having mastered the principles, the sailors get two crammed courses on practical boiler operation, during which they work with three school boilers which simulate as nearly as possible actual shipboard installations. Here they learn to observe the shape and color of the flame, the furnace appearance and the resultant CO_2 obtained under various conditions governed by air pressure and burner adjustment.

Refractories, fuel oil, feedwater and auxiliaries come in for their share in the courses, too. The students are taught to adapt firing procedure to different oils, important today when our ships are likely to receive fuel in foreign countries. In feedwater work they learn to look out for contamination and to make correct alkalinity and hardness tests. As to auxiliaries, they are shown by demonstrations the operating principles of turbines, rotary pumps, speed-regulating and limiting governors.

The students are given a down-to-earth explanation of refractories, their purposes, compositions and uses. Properties and uses of plastic firebrick, plastic chrome or baffle mix; expansion joints and anchor bolts come in for their share of discussion. Also included are ways to tell when repairs are necessary and how to make them. Each practical work period enables the students to build up a typical boiler front and side wall. Forms are provided for casting the baffle mix or castable refractory, as it is sometimes called. Simulated stud tube dividing walls are also provided to give experience in the proper pounding in and setting of plastic chrome ore. Front and side walls built by the students are cut out in various places to afford practical experience in making emergency repairs.

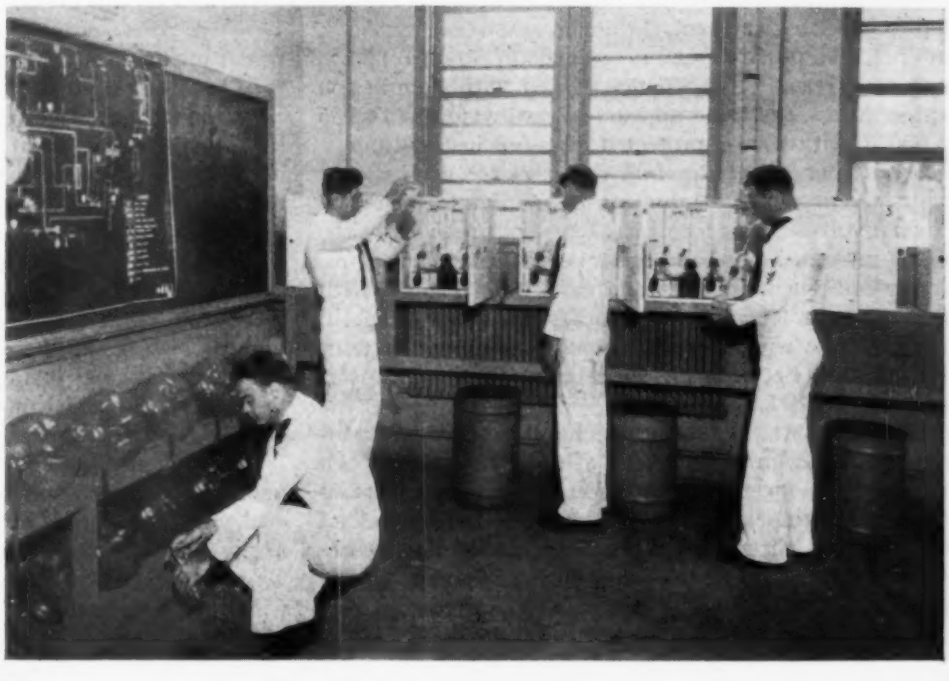

Fig. 4—Students learning to make feedwater analyses

Progress in Steam Generation

Activity prevails in both the utility and industrial power plant fields and, although there have been no major departures from practice over the last few years, steam generator design is reflecting changed fuel conditions by providing conservative furnace heat releases, lower gas velocities and stressing efficiency. In the industrial field spreader stoker firing continues to increase and there is a growing demand for small standardized complete units.

WITH the easing of wartime restrictions on power plant construction following the defeat of Germany and the subsequent lifting of such government controls, plans for the expansion of utility capacity to meet anticipated post-war growth in electric load became active in the late summer and fall. This resulted in the placing of numerous orders for substantial extensions to existing plants. Although relatively few new stations were projected, several new plants that had previously been authorized went into service late in the year; these included the Tidd Station of the Ohio Power Company and the Jennison Station of the New York State Electric and Gas Company. Of the new capacity, some will be available in the latter part of 1946 and more early in 1947; the latter including some new stations now under design. Utility production of electricity in 1945 amounted to approximately 221 billion kilowatt-hours which was about 3 per cent under the wartime high of 1944.

In general, steam-station practice, as reflected by new construction, follows the immediate pre-war pattern with such refinements in design as have been dictated by experience over the last few years. While steam conditions in the utility field are still divided between the 1400-psi, 935–950-F and the 900-psi, 900-F groups, the former appears to predominate. Still higher pressures, of the order of 1600 psi, are found in some instances for topping; and, as a result of experience gained with high steam temperatures, the trend appears toward wider use of 935 to 950 F, with 1000 F projected for a few installations.

Because of increasing fuel costs, closer attention is being given to the attainment of maximum efficiency which involves higher feedwater temperatures, even up to 450 F in some cases, and wider application of heat-recovery equipment with low exit gas temperatures. With respect to the latter, improvements have been made in air heaters to withstand corrosion due to low exit temperatures and better means for cleaning the heat-transfer surfaces.

The more extensive use of mechanization in coal mining is resulting in the delivery of coals with higher ash content. To meet this situation the later designs of steam-generating units are employing lower gas velocities to avoid cutting of the tubes, and provisions are being made for better ash and slag removal. Among the large units now under design and construction furnaces of the dry-bottom type predominate.

Liberal furnace volumes with corresponding lower Btu heat release are being employed to meet the changed coal conditions, particularly lower ash-fusion temperatures. Maintenance of desired steam temperatures, with lower heat releases at low loads, has been greatly assisted by the use of vertically adjustable burners in tangentially fired furnaces which continue to be favored for large heavy-duty steam-generating units. Moreover, considerable improvement in burners of all types has been made during the war period.

Feedwater treatment, particularly where high makeup is involved, continues to be a problem in many plants, although the employment of potassium treatment has led to beneficial results in numerous cases. Deposits of black magnetic oxide on the inside surfaces of boiler tubes have been prevalent in boilers of all types operating under widely different steam conditions. The greater part of this is believed to be of outside origin, as are also the copper deposits. While considerable attention has been given to investigating such deposits, opinions differ as to their importance. However, the increasing use of acid washing has alleviated the seriousness of internal deposits of all kinds and, in addition to saving time, has also made possible greater flexibility in the design and arrangement of component parts of steam-generating units.

During the past year an order was placed for another million-pound-per-hour steam-generating unit to operate at 1625 psi 955 F and a number of others approaching this capacity are now under construction. More large single-unit installations, of one boiler and one turbine, are indicated, which arrangement effects saving in piping, as well as offering certain operating advantages. One such installation now under construction consists of a 100,000-kw condensing turbine-generator served by a single boiler.

While pulverized-coal firing predominates in central stations, it is important to mention that the boilers in the recently completed Jennison Station are fired by 672-sq ft traveling-grate stokers burning No. 4 buckwheat anthracite. These are the largest stokers of this type yet employed in central station service.

In the industrial power plant field considerable activity prevails. To what extent this results from the necessity of replacing obsolete or war overworked equipment, or to what extent the demand has been stimulated by anticipated peacetime production, is difficult to assess.

Among the larger industrial plants steam pressures of around 400 to 450 psi still predominate, but there is an increasing number of new 600-psi installations. Still higher pressures are being employed in individual cases, in one exceptional instance 1600 psi, 935 F. Some of these large industrial units fall in the same design category as those for central stations.

Although most industrial units of around 100,000 lb per hr capacity, or greater, are employing pulverized coal, there is a marked trend toward spreader-stoker firing, particularly for medium size and small units. This is dictated by the ability of such units to burn a wider range of coals, in line with present coal market conditions, than other types of stokers. Combustion

control and provision for cinder recovery is general, and in many cases the cinders are re-introduced into the furnace. Continuous discharge stokers of this type are gaining favor especially in the larger capacities.

Gas firing continues popular among plants in the Southwest, and in some cases oil is specified as fuel; but in the East and South the uncertainty as to future oil availability and price has been responsible for a preponderence of coal-burning units. Where oil is specified, it is quite general to make provision for pulverized coal as an alternate fuel. In fact, recent boiler installations in certain eastern refineries are now burning pulverized coal. This condition results from the widespread employment of catalytic processes in refining which permit maximum extraction of gasoline from the crude with minimum heavy residual oils, the demand for which is likely to be absorbed to a large extent by marine demands.

Among the smaller industrial plants there is a demand for more or less standardized steam-generating units of the so-called "package" type fired either with spreader or single-retort underfeed stokers.

Although the year just passed has brought to light marked advances in the development of the gas turbine, as an outgrowth of jet propulsion for aircraft, this type of prime mover is likely to find its principal field of application in aviation and perhaps to a more limited extent in locomotive drive and special marine applications. Considered opinion is that it will be some time before the gas turbine in large capacities will enter the field of stationary power generation, except, of course, as at present in connection with oil refinery process. Nevertheless, experience with temperatures encountered in gas turbine work will likely have bearing on further developments in steam generation, in which field research, supplemented by field investigations, is assuming increasing importance.

Since the advent of the atomic bomb, there has been much speculation as to the possibilities of adapting nuclear energy to power production. In the first place, it will probably be some time before a definite pattern of military and political control of atomic energy is adopted after which science will give attention to peacetime uses. Many well-informed individuals have expressed the opinion that it should be technically possible to employ such energy for power production, but none is sure that it will be economically practical. There are so many hurdles to be overcome in the control of the liberated heat, protection to personnel and probable high investment costs that, from present indications, there is little likelihood of it becoming a serious competitor of present methods of power generation for many years to come. However, considering the obstacles that have been successfully surmounted by scientists and engineers in the past, it would be most reactionary to discount the probable ultimate success, perhaps for special applications. Physicists have paved the way and it will be up to the engineers to follow through.

Here is a typical boiler refractory wall in bad repair. Note how the refractory cement has loosened at the joints and the firebrick fallen out.

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Efficiency Bureau Functions

By J. R. MICHEL

Commonwealth Edison Company

In reporting the A.S.M.E. Annual Meeting in the December issue a brief account was given of the panel discussion on "Reducing Losses in Power Operation and Consumption." One of the participants in the panel was J. R. Michel who described the functions of the Efficiency Bureau of the Commonwealth Edison Company, Chicago. Upon request, Mr. Michel has since provided us with the complete text of his paper, together with an organization chart, which we are here pleased to publish—Editor.

THERE are four steam-electric generating stations in Chicago, ranging in capacity from 187,500 kw to 437,500 kw, which operate with throttle steam conditions up to 1250 psi, 925 F. Power plant equipment in these stations could well constitute a panorama of generating station development, since Fisk Station, the earliest of the four, was the first large all-turbine power station in America. There were many firsts included in the development of the stations and it is with the performance of these stations and station equipment, and with the practical or applied research and study concerning development that the Efficiency Bureau of the Operating Department works.

The accompanying chart shows the operating organization, from which it will be noted that the Efficiency Bureau reports as staff to the Superintendent of Generating Stations. The group is comprised of a relatively small number of men in normal times consisting of some eight or ten reporting through supervisors to the superintendent. The supervisors started in the efficiency group, progressed through station supervisory operating positions and were advanced to their present positions. All in the group are engineering graduates.

Two men have remained in the group a considerable length of time and they coordinate and guide the actual testing work of the younger men. The engineering graduates start as engineers, junior grade, and as they learn to apply their theory to practical power plant problems, they assist in performance tests of auxiliary equipment and later take more and more important parts in testing and analyzing the performance of major equipment. Thus they become generally familiar with the stations of the system from the coal plants through the boiler plants, turbine rooms and the stations' electrical and maintenance divisions. The experience gained from testing work, analysis of performance difficulties, determination of station performance and preparation of operating manuals and operating procedures, in a relatively few years prepares them for operating positions. The Efficiency Bureau as we know it today was organized in 1921.

Aside from the regular work performed, the Efficiency Bureau has rendered a real service in preparing men for supervisory operating positions. The present chief engineers in each of the stations at some time worked in the efficiency group and this is true also of a large percentage of other operating supervisors, especially those engaged in the station turbine and steam generating divisions. In the discharge of their responsibilities these supervisors constantly use the training received in the efficiency group.

While it is true that the training received has benefited those who started in the efficiency group and has improved the performance and speeded the advancement of those who have progressed from it to operating positions, it is also true that many excellent supervisors progressed from operating employee classifications.

All employees are urged to participate in and benefit from outside study courses which apply to their work. Those starting in operating positions who complete sufficient studies to fulfill the requirements for Efficiency Bureau work frequently are transferred to that division so they may benefit from its training. This interchange of men in operating and testing positions has been of real advantage to all concerned and has resulted in a spirit of cooperation between operating and testing groups that is excellent. The present difficulty is to satisfy the requests of operating supervisors for test services and aid in the analysis of problems that require special instrumentation facilities and manpower for special analysis.

The group prepares monthly summaries of station performance as one of its regular duties. These are detailed analyses setting forth the month's performance of each piece of station equipment that to any appreciable degree affects the overall performance of the station. The reports are submitted to the Superintendent of Generating Stations who, after approving them, sends them to the supervisors concerned. Deviations from desired performance are set forth and, where necessary, corrective measures are instigated by the superintendent or by the operating supervisors.

Equipment performance which requires frequent or daily checking is accomplished through field checks, the procedures for which are set up by the testing group. These include checks depending on periodic or day-to-day observations in operation or data drawn from log readings. They are assembled in the form of charts or tabulations by the operating personnel who are guided in their procedure by the indications.

The testing of plant equipment which requires the collection of a considerable amount of precise data, such as in heat rating a turbine or a plant section, is performed by the efficiency group. The results of the tests are calculated and assembled in the form of reports. These indicate the results of repairs or changes and are sent to those concerned by the superintendent. In many cases the operators in cooperating with the testing group are aware of the results before the report is issued.

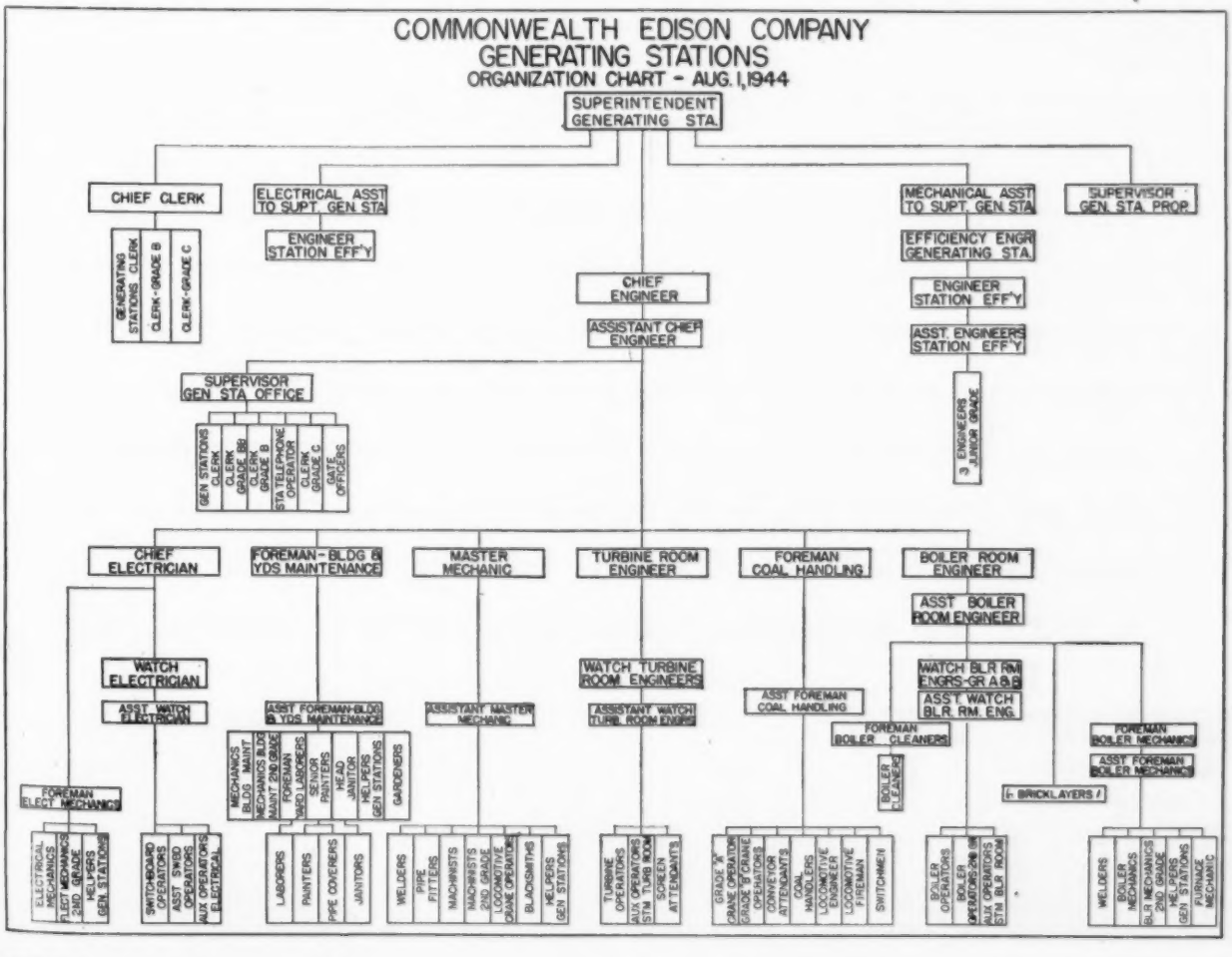
Statistical studies and engineering investigations of present equipment or operating conditions and studies of the effects of proposed or suggested changes in any items of steam generating equipment are subjects that receive attention. Proposed replacements or alterations are carefully studied to determine the resulting effects on investment, operating costs and performance. Worthwhile projects are initiated and tentative designs are made for the Engineering Department for those installations or rearrangements that are commercially desirable.

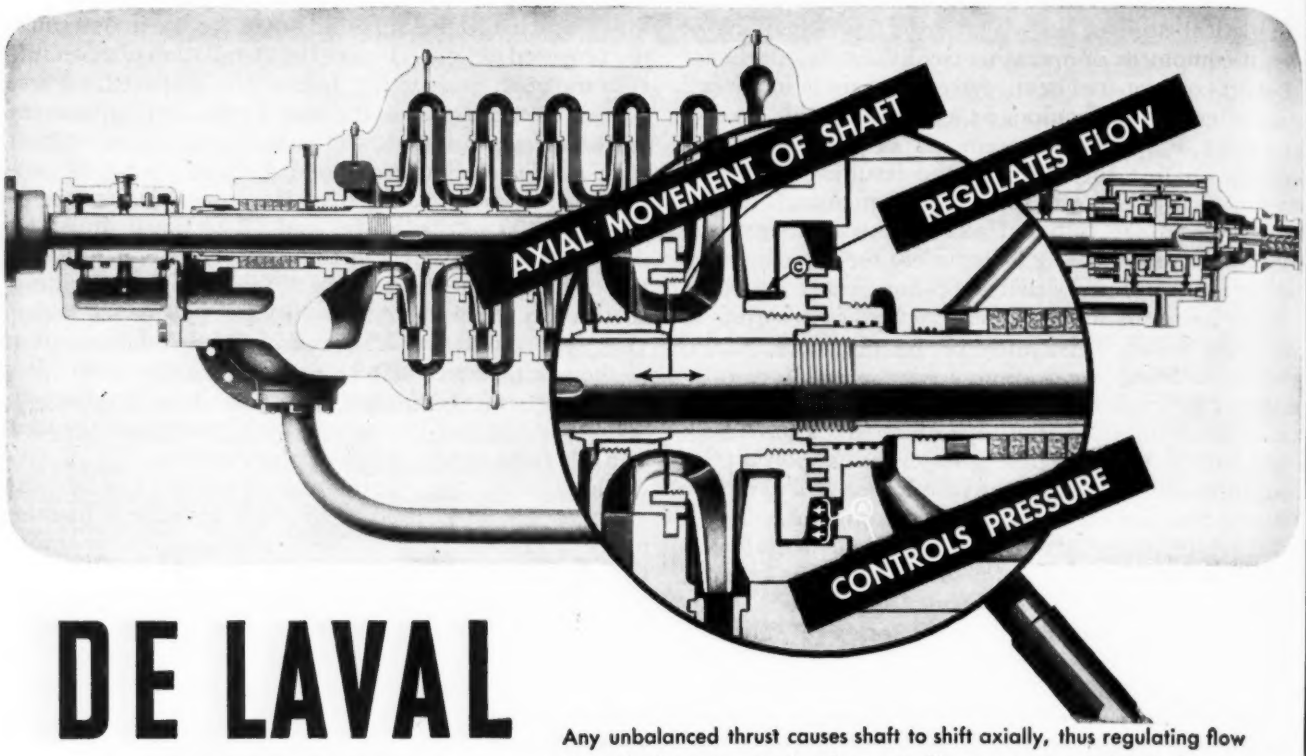
Major items involving process, such as chlorination of circulating water, application of overfire air to chain-grate stoker firing, application of regenerative feedwater heating, gas firing, and operation with washed coal, are studies involving pilot plant operation which have been conducted by the efficiency group. An important investigation which required the installation of a complete boiler for test purposes is under way at present. Many of the investigations have resulted in developments affecting methods of operation and plant design or major plant changes. In many cases economy has resulted.

Not of the least importance is the library of Efficiency Bureau reports. These form a reference of development, history and statistics. They are repeatedly referred to in connection with current problems with the equipment under study. These reports, now numbering some 1500, cover nearly all subjects of power plant operation from coal sampling through the incremental loading of the units of the system. They have proved to be of a value far exceeding the cost and trouble of formal preparation.

When new installations or major plant additions are considered the heat balances are checked. These checks are submitted to the Superintendent for use in determining proposed design. Before the installation of new units is completed, instruction books are prepared. These contain descriptions of the new equipment, equipment performance guarantees, sectional drawings of equipment with pertinent dimensions and detailed operating procedures. Some of these operating manuals contain as many as 150 printed pages and 75 sectional drawings. After preparation of the manual and before operation of the new equipment, classes are held for the operators. Instructors for these classes are drawn from the supervisory operators who will be responsible for the operation of the equipments. After the unit is in operation, performance tests are conducted by the efficiency group to determine whether the included equipment and the unit as a whole have met the design guarantees.

Throughout the Generating Stations Department organization, line responsibility for operation, maintenance and performance has been maintained. The activities of the efficiency group are of a staff nature. This has proved adequate over the past twenty-five years for checking performance, trouble shooting, starting new equipment in operation, accomplishing the practical research required for process development and for the training of personnel for responsible operating positions. Evidence of the effectiveness of this type of organization is indicated by those contributions it has made toward reducing the combined average heat rate of the stations some 10,000 Btu per kwhr over the past twenty-five years and by the results of investigations which have contributed to designs used by ourselves and associated companies.





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Electric Drives for Steam-Electric Generating Station Auxiliaries

The following excerpts are from a paper by W. R. Brownlee and J. A. Elzi, both of the Commonwealth & Southern Corp., presented by the power generation committee of the A.I.E.E. and recently released for publication. The authors review the trend toward all-electric drives for steam station auxiliaries, because of flexibility, convenience, low operating cost and comparable investment cost, and stress the advantages of transformers as the sole means of station power supply. The views expressed are backed by experience with approximately 500,000 kw capacity in modern pulverized-coal-fired plants operating at 850 psi, 900 F.

BEFORE the advent of the extraction turbine, the need of steam for feedwater heating strongly favored small steam turbines as drives for most of the station auxiliaries. Multi-stage bleeding brought about a critical examination of operating costs of turbine-driven auxiliaries, and resulted in the application of electric motors to many of them, certain steam turbine drives being retained either to obtain convenient variable speed operation or with the objective of securing greater reliability for critical drives.

Many factors have contributed to the improved reliability of electrically driven auxiliaries. Modern motors are highly reliable and variable speed couplings provide flexible and efficient operation where required. The growing interconnection of both stations and systems makes it feasible to secure emergency electric power for auxiliaries not only from several points within a station but from remote sources as well. Several years' experience has demonstrated that the proper coordination of driven equipment, motors, control, and power source insure an extremely high degree of reliability. Many stations now operate with all auxiliaries electrically driven, with the minor exception in some cases of the turbine bearing oil pump, which is furnished by the manufacturer as a part of the turbine.

Basic Requirements

The requirement of reliability for many auxiliary drives is most important. Especially with pulverized fuel-fired boilers, the interruption for even a few seconds of certain critical drives may result in flame extinction, and the resulting necessity of purging the furnace system and relighting may cause a serious (though temporary) loss of capacity. Thus the overall system must be made relatively immune to short-time disturbances but without sacrificing the simplicity and flexibility which are so essential to successful operation. Adequate safety interlocking is required, but must be scrutinized for possible hazards to reliability.

For some of the drives, variable-speed operation or its equivalent is necessary. Where storage capacity can be secured readily, the automatic intermittent running of constant-speed motors provides convenient, flexible and low cost performance. For other auxiliaries, the use of constant-speed motors with variable-speed couplings can provide the desired solution.

While consideration of cost is secondary to that of reliability, a careful consideration of all factors will facilitate low first cost design without any measurable sacrifice in reliability. The low operating cost of electric-driven auxiliaries is inherent when compared with steam-driven auxiliaries.

Motor Application

By far the largest portion of motors used for station auxiliary drives are three-phase, squirrel-cage, induction motors conforming to NEMA standards as regards starting current, starting torque and maximum torque. In spite of the requirements of high reliability only a very few motors and auxiliaries, such as boiler feed pumps, pulverizers and circulating water pumps, are installed in duplicate. For this reason, particular attention is paid to the mechanical and electrical construction of the motors purchased. This does not mean that the motors need to be of special design or construction.

A few of the small motors are rated 220 volts, but most drives use either 440- or 2300-volt motors. An economic survey taking into consideration the cost of motors, control equipment and the station distribution system has resulted in a decision to place the dividing line between the use of 440-volt and 2300-volt motors at approximately 100 hp.

Full voltage starting is used for both 440- and 2300-volt motors. This permits the use of a low cost control scheme which is simple and direct in its operation and lends itself to quick automatic transfer from one power source to another in an emergency. It also provides full starting and pull-in torque for normal voltage conditions. It may, however, be necessary at times to start an essential auxiliary when the voltage at the motor terminals is below normal as the result, for example, of the loss of a sizable amount of generation from the system. The speed-torque requirements of all auxiliaries are given careful consideration and motors having adequate speed-torque characteristics at the minimum operating voltage are selected.

For some applications such as certain types of pulverizers the starting torque is the critical value, and if a

motor is selected having adequate torque to start the pulverizer during low voltage conditions no difficulty will be experienced in bringing the pulverizer up to speed. In other applications such as boiler feed pumps the starting duty is relatively light, but the torque curve of the pump may rise very rapidly with speed and in this case it is necessary to check the speed-torque curve of the motor under minimum voltage conditions to make sure that it remains above the pump characteristic at all speeds.

Motors having normal starting current are usually provided since light flicker, due to motor starting, is not usually a problem when transformers are used for station power supply. Coordinated unit design results in satisfactory operation from the standpoint of disturbances resulting from starting the largest motor or the transferring of a group of running motors from one bus to another.

Mechanical Construction and Insulation

In order to assure reliable continuous operation, careful consideration is given to mechanical construction. The motor windings and rotor bars must be braced to withstand the stresses due to full voltage starting and must be thermally adequate for the current associated with it. In so far as practicable, the construction should be such as to provide ease in making periodic inspections and checks. This means, for example, that it should be easy to check the oil level in the bearings and to make sure that the oil rings are performing properly. Provision should be made for checking bearing temperatures, and suitable openings for checking air gaps are essential. Proper end play is important, especially in 3600-rpm motors, and the motor should be so constructed that this can be checked readily.

Motors with insulation specifically designed and treated for power station service are now generally available and should be used for all auxiliaries. This insulation is moisture- and dirt-resistant and with proper maintenance can be expected to give satisfactory service without the necessity of using splash-proof or totally enclosed motors. Drip-proof motors are provided where there is a possibility of water dripping on the motor.

Both Class A and Class B insulation are used. In general it is easier to obtain satisfactory Class A insulation for power station service; and Class B insulation is specified only for motors operating in ambients above 40 C, such as draft-fan motors.

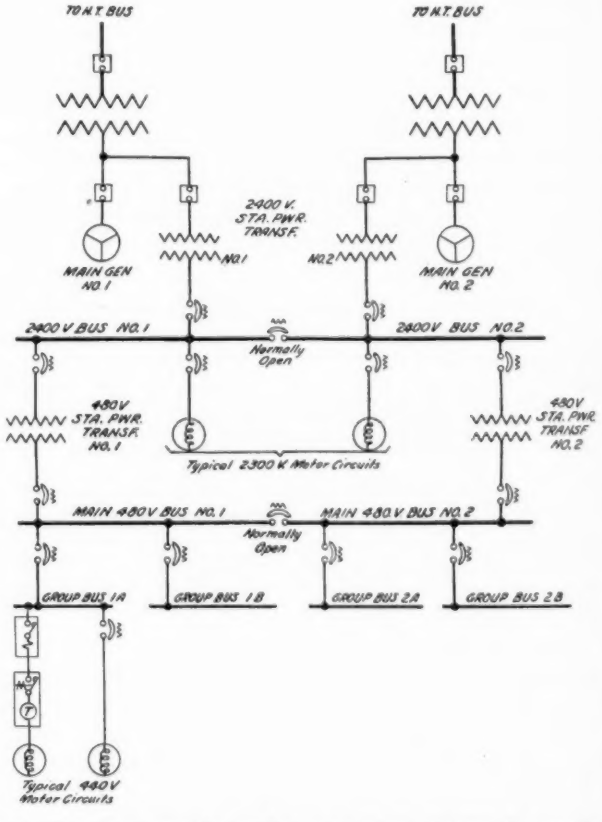
Speed Control

For most station auxiliary applications constant-speed drives are used. The induced- and forced-draft fans are an exception to this. The power requirements of these fans are substantial, and their speed adjustment is controlled automatically by the combustion control equipment.

In many of the earlier plants the motors for these drives were of the wound-rotor variable-speed type. However, equal efficiency and better control can be provided with constant-speed motors and variable-speed couplings of the hydraulic or magnetic type. These are in most cases used to provide the entire range of speed control and have proved quite satisfactory, responding very well to the combustion control equipment. In some instances two separate motors are provided with different constant-speed ratings, with dampers to provide intermediate control.

Power Supply Systems

The choice of a system for supplying power to electrically driven auxiliaries is a vital one. The primary objective of adequate reliability must be obtained, but this does not mean that the most elaborate and expensive scheme is necessary or even desirable. One of the important advantages of electric drive for station auxiliaries in an interconnected transmission system is that power may be secured from a large number of sources and transferred instantly from a central location. The extension and improved performance of interconnected power stations and systems have increased the popularity of the unit system of plant design; that is, one boiler, one turbine, and one step-up transformer operating as a unit, with electrical connections with other units made at the high-tension bus only. The interconnected system can compensate for the loss of any one unit, and accordingly the statement has been made that the overall reliability of the station auxiliaries need be no greater than that of the main units. This is true with certain minor exceptions. In the case of an emergency outage of a main generator for a temporary cause, it may be necessary to provide emergency service within a short time to the boiler feed pump. If the interruption to the main unit is long enough for the turbine to stop turning, then the availability of emergency power for the auxiliary turbine turning motor will save an additional delay of two or three hours in restoring the unit to service.



Typical power supply and motor connections for station auxiliaries, with transformers as source of supply

In early applications of electric drive to include essential auxiliaries, it was sometimes thought necessary to provide an entirely separate house turbine-generator, supplemented with an auxiliary generator on the shaft of the main unit and a transformer source. Such an installation was so expensive as to offset in part the $1^1/_2$ to $2^1/_2$ per cent reduction in operating costs achieved with electric drive. Experience soon showed that the costly house turbine-generator was unnecessary and added very little to reliability. The upward trend in steam pressures and coordinated bleeding cycles was also a factor in the gradual abandonment of the house turbine.

The less costly auxiliary generator driven on the shaft of the main unit is still much more expensive than a transformer. The principal advantage of the shaft generator is that the auxiliary bus supplied from it is not exposed to voltage disturbances originating on the transmission system. On the other hand, the line starting of large induction motors from a shaft generator may involve serious voltage disturbances of several seconds' duration which are not encountered with transformer supply.

Careful analysis of fundamental requirements has shown that the proper coordination of the characteristics of motors and control with those of the driven equipment provides adequate reliability using transformers for the sole supply of auxiliary power. Some of the factors contributing to the improved reliability of systems using transformers are:

1. Coordination of control methods to avoid unnecessary interruptions.
2. The more rapid clearing of transmission system faults.
3. The use of squirrel-cage induction motors with full voltage starting.
4. The choice of power sources to provide a natural "cushion" against external power system faults.

Special tests have been made to check the overall operation of the systems and subsequent experience provided further confirmation.

Typical Connections Employing Transformers

The accompanying diagram illustrates a typical scheme of connections with the station power transformers connected to their respective main units at generator voltage, and with the latter grouped in pairs for emergency operation of both sets of auxiliaries from either main generator. Transfer of an entire group of auxiliaries may be made from the control center and is normally accomplished automatically in case a station power transformer separates by differential relay. This automatic transfer may also be initiated by operation of the relays protecting the main transformer bank. Reliability suitable for a unit system is obtained with single busses which are well protected electrically and mechanically. In the case of the 480-volt system, the relatively large number of motors makes it desirable to divide them among group busses as shown so as to limit the total exposure on the main 480-volt busses. Experience to date has not shown the desirability of providing "voltage chasing" schemes.

Furthermore, the main step-up transformer of a "unit" installation provides a natural cushion for the station auxiliary bus against transmission faults.

Control and Switching

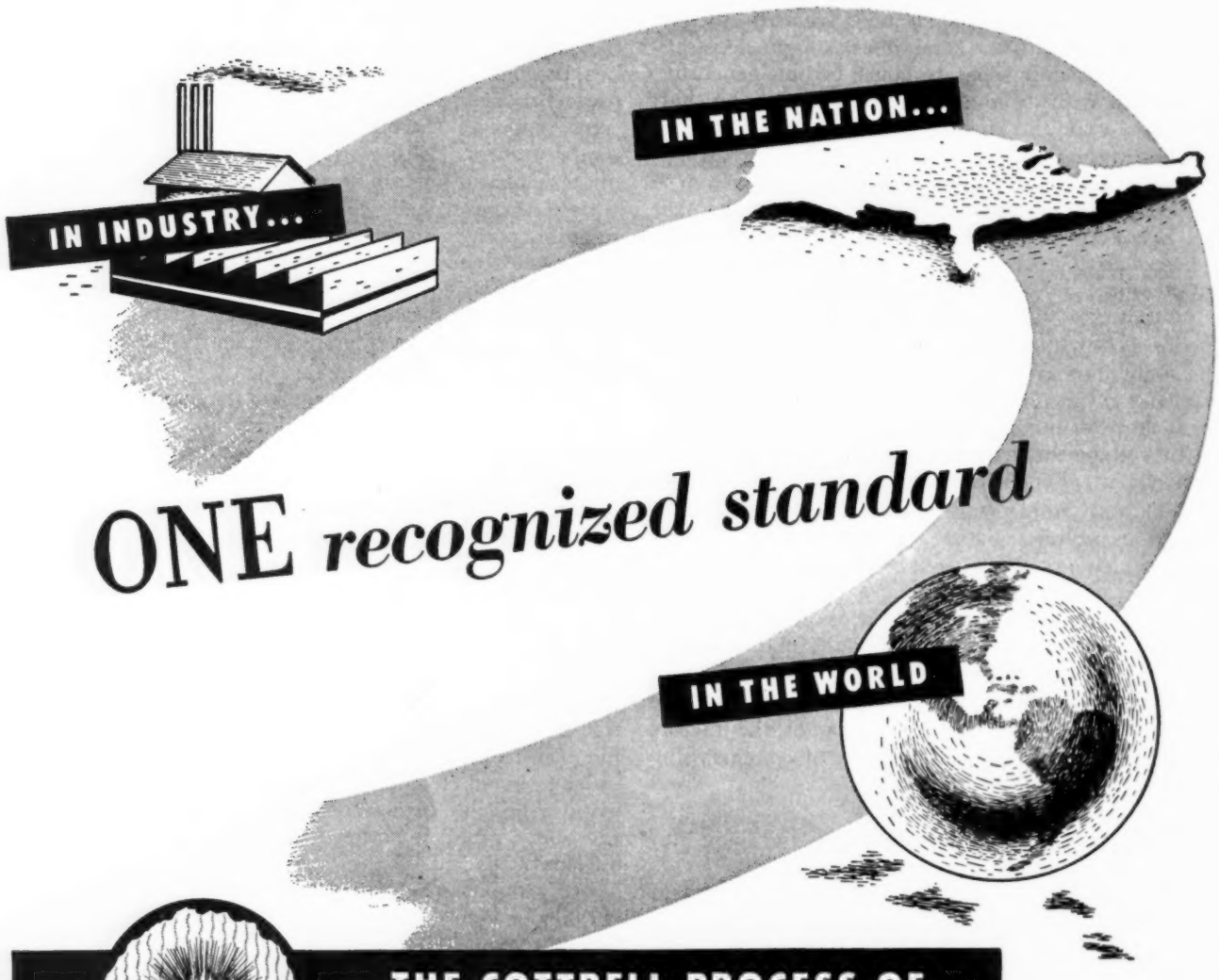
As shown, the 2300-volt motors are connected to the bus through circuit-breakers which provide automatic protection against faults in the motor or circuit (and in some instances thermal protection) and also serve as motor starters. Either air or oil circuit-breakers of adequate interrupting ability are used, but the trend is toward the use of air circuit-breakers because of their superior performance for starting duty. Air circuit-breakers also have an advantage from the standpoint of inspection and maintenance of contacts. This is of considerable importance in view of the fact that these breakers are operated much more frequently than breakers on distribution circuits.

For 440-volt motors, the control for many of the individual motors consists of a small air circuit-breaker with instantaneous trip attachment for fault protection and a magnetic contactor for starting duty. For nonessential motors, standard industrial control equipment is satisfactory. For some applications, however, latched-in contactors or air circuit-breakers suitable for motor starting service are required.

In a pulverized-coal plant, it is necessary for safety and operating reasons that the sequence of starting and stopping certain motors be carefully interlocked. For example, the induced-draft fan is started first. This is followed in sequence by the starting of the forced-draft fan, the exhauster, the pulverizer and the feeder. In order to avoid clogging of the fuel supply system and to avoid a possible explosion if any piece of equipment in the above group is stopped, provision is made to stop automatically all of the motors ahead of it. In the above group, if the exhauster stops for any reason, its breaker or contactor is opened and an auxiliary switch trips the pulverizer which in turn trips the feeder. It is essential that the device which initiates the tripping sequence respond to failure of the driven quantity and not simply to undervoltage, because stoppage may be the result of a sheared pin, a broken shaft or some cause other than failure of power supply to the motor. In the example taken, the emergency dampers are tripped by the differential pressure relay, damped to give a slight time delay. This, in turn, trips the exhauster motor and the remaining motors in the sequence.

While undervoltage protection is not required for full voltage starting motors, the use of standard magnetic starters for 440-volt motors would provide "unintentional" low-voltage protection. Most of these starters will drop out at around 50 per cent of normal voltage and remain open unless a latched-in type of auxiliary relay is used. This is not serious for automatic-start intermittent running equipment with storage capacity such as the feeder, house service pump, combustion control air compressor, and condensate pump provided they are not included in any interlocking scheme. Standard starters even with latched-in auxiliary relays are not suitable for motors in an interlocked scheme because the auxiliary switch on the contactor would start the tripping sequence of the other motors and emergency safety devices in the series. For such motors, either latched-in contactors or breakers suitable for starting duty are used.

Latched-in contactors or circuit-breakers are also provided for highly essential motors, even though they may not be part of an interlocked sequence. This permits utilization of all available power, even at voltages 50 per cent below normal.



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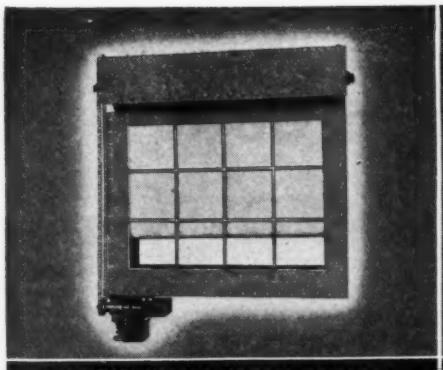
Recommended Standard Coal Sizing

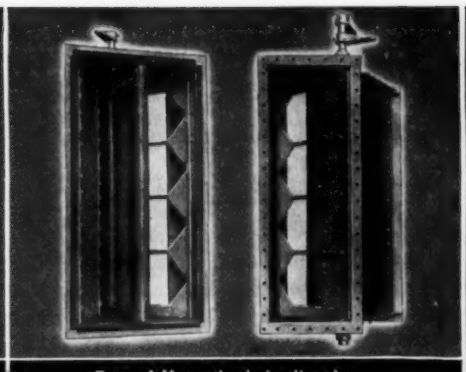
In the January 1945 issue we published a list of coal sizing recommendations as tentatively compiled by Combustion Engineering Company, with the idea of stimulating constructive comment that could lead to a recommended standard of coal sizing for different methods of firing. As anticipated, a number of helpful comments were received from authoritative sources, with particular reference to the changing coal market conditions. These suggestions were carefully considered and investigated by those who compiled the recommendations, from both availability and operating angles, and modifications in some categories were made in the tentative recommendations. The sizings as revised are as follows:

Equipment	Fuel	Sizing	Remarks
Traveling Grate	Anthracite	No. 3 Buckwheat (Barley). All through a $^{3}/_{16}$-in. round mesh and not more than 20% through a $^{3}/_{32}$-in. round mesh	Standard
	Anthracite	No. 4 Buckwheat. All through a $^{3}/_{32}$-in. round mesh and not more than 20% through a $^{3}/_{64}$-in. round mesh	Standard
	Coke Breeze	All through a $^{5}/_{8}$-in. round mesh and not more than 50% nor less than 25% through a $^{1}/_{8}$-in. round mesh	Should contain 8 to 10% moisture and not less than 2% volatile matter. (See Note)
Traveling Grate and Chain Grate	Mid-Western Bituminous and Lignite	1-in. Nut and Slack, not more than 50% slack through $^{1}/_{4}$-in. round mesh	Coal should be tempered to 15% moisture. (See Note)
Spreader	Eastern Bituminous (Friable)	$1^{1}/_{4}$- or $1^{1}/_{2}$-in. Nut and Slack, not more than 50% Slack through $^{1}/_{4}$-in. round mesh	See Note
	Eastern Bituminous (non-friable) and Mid-Western Bituminous	$^{3}/_{4}$-in. Nut and Slack, not more than 50% Slack through $^{1}/_{4}$-in. round mesh	See Note
Underfeed Stokers: Type *E* Multiple - Retort Skelly and Low Ram	Eastern Bituminous (Friable)	2-in. Nut and Slack, not more than 50% Slack through $^{1}/_{4}$-in. round mesh	For Multiple Retort. (See Note)
	Eastern Bituminous (Non-friable) and Mid-Western Bituminous	1-in. to $1^{1}/_{2}$-in. Nut and Slack, not more than 50% Slack through $^{1}/_{4}$-in. round mesh	For Multiple Retort. (See Note)
Skelly	Anthracite	No. 2 Buckwheat (Rice). All through a $^{5}/_{16}$-in. round mesh and not more than 15% through a $^{3}/_{16}$-in. round mesh	Standard
Pulverizers	All Coals	$^{3}/_{4}$-in. Nut and Slack	

NOTE: Fuel to be delivered across stoker hopper without segregation.



Type SVH Heacon Damper motorized for combustion control.



Type LV vertical, inclined or horizontal duct.

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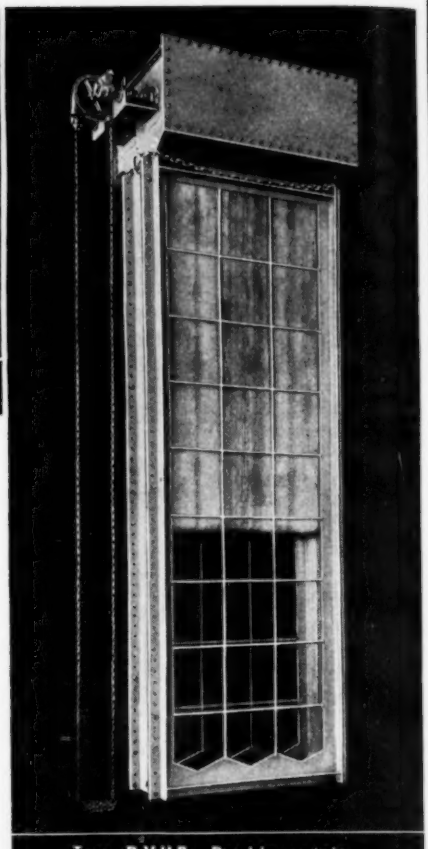
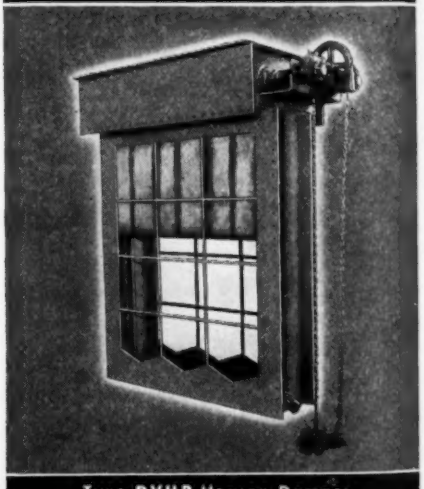
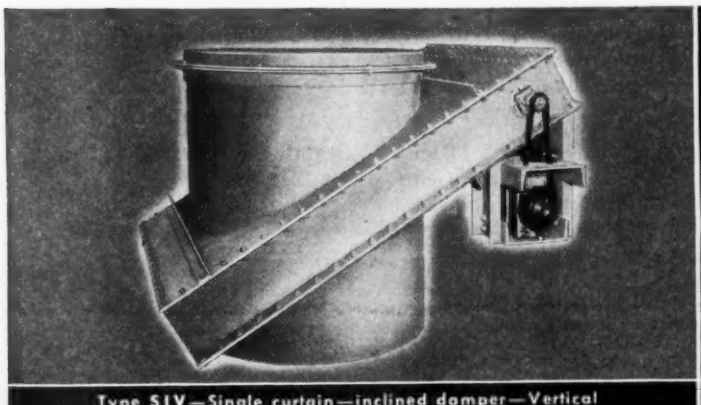


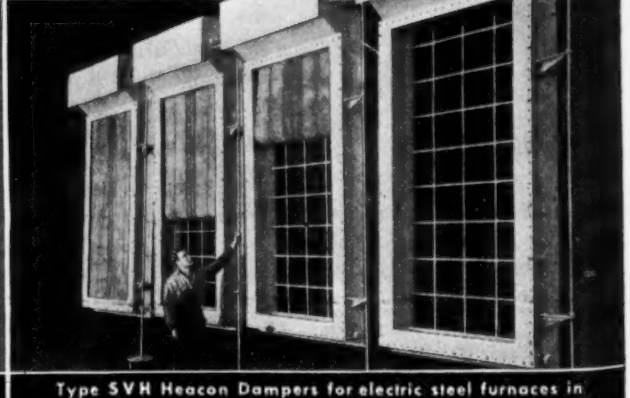
Type DVHR—Double curtain—Reversing flow. Regulates flow in either direction.



Type DVHR Heacon Damper controlling reversing flow in bypass in eastern airport.



Type SIV—Single curtain—inclined damper—Vertical duct. Regulates flow in one direction.



Type SVH Heacon Dampers for electric steel furnaces in one of the new steel plants.

Simple Test for Substandard Coals

At infrequent intervals, analysis of a coal shipment reveals a below normal figure for ash-free, moisture-free heating value usually accompanied by a rather high moisture content. While such coals are usually called "crop coal," it is not certain whether this substandard state is due to weathering or that, due to geological circumstances, coalification has not been completed. Such coals at best cause a substantial increase in the consumer's fuel bill and at times may affect the load-carrying capacity of the boilers.

A simple test has recently been encountered which apparently permits easy and rapid detection of such coals. A few small pieces of the coal about the size of a pea are placed in a beaker and sufficient concentrated ammonium hydroxide is poured in to cover the pieces of coal. Substandard coal causes a distinct brown color to develop in the ammonia solution, while normal coal develops no color except perhaps a turbid gray due to suspended coal particles. The test appears to be very sensitive, since in a washed coal which normally has a very consistent H value, deficiencies of only 100 Btu cause a distinct brown color.

The test as developed in the Indianapolis Power & Light Company laboratory has only been used as a qualitative check. While a quantitative test might be based upon this reaction, it seems doubtful whether it would be much simpler than the usual calorimeter determination.

Such limited testing as has been done, indicates that this test does not show up the drop in heating value which is usually found in coal that has been stored in the open for several years.

Experience with this test has been limited to a few strip mines in the Southern Indiana field. Since theory points to a reaction between the humic acids in the coal and the alkaline ammonia solution as a cause for the brown discoloration, it may be that the test would have general application to other mines and other coal fields.

R. W. GAUSMANN
Indianapolis Power & Light Co.

Blade Tips Approaching 1000 Mph

In a steam turbine the limit to volume of steam flow, and hence to economical capacity, is set by the length and diameter of the blades in the last row. As the blades get longer the centrifugal forces tending to pull them out by their roots become enormous. Also the velocities of the blade tips at high turbine speeds become very large—which places emphasis on the best airfoiling.

Heretofore, the longest blade for the 3600-rpm turbines has been 20 inches. The new blades, designed by Westinghouse Engineers and soon to undergo tests, are 23 inches long. At 3600 rpm this will mean a blade-tip velocity of 1520 ft per second—one-third greater than the speed of sound. They will make possible steam turbines that can deliver 40,000 kw from a single-cylinder 3600-rpm condensing unit or 80,000 kw from a tandem 3600-rpm condensing unit. These outputs compare with 30,000 kw and 65,000 kw of the present largest 3600-rpm machines.

1945 Coal Output

Estimates based on reports of car loadings indicate a bituminous coal production during 1945 of 574,200,000 tons. This is 45 million tons, or 7.3 per cent, under that for the year 1944.

The National Coal Association, speaking for the producers of bituminous coal, put 1946 prospective requirements of the United States at 525 million tons, which figure includes an allowance of 25 million tons for shipments to Canada and overseas during the current year. This estimate is based on the assumption that the industry will escape further crippling strikes.

In the anthracite field the Anthracite Institute gives the 1945 production as approximately 51 million tons, which figure represents a decrease of 14 per cent from that of the preceding year. A substantial contributing factor to the decreased output of anthracite was manpower shortage at the mines.

Edison Medal Award to Philip Sporn

The Edison Medal for 1945 has been awarded by the American Institute of Electrical Engineers to Philip Sporn, executive vice president, American Gas & Electric Service Corporation, "For his contributions to the art of economical and dependable power generation and transmission."

Mr. Sporn graduated in electrical engineering from Columbia University in 1917 and joined the American Gas & Electric Company in 1920, progressing through the positions of protection engineer, communications engineer, transmission and distribution engineer, station engineer, chief electrical engineer and chief engineer to his present position as executive vice president. Under his supervision much of the present facilities of the A. G. & E. System have been designed and installed.

The medal will be presented to Mr. Sporn on Wednesday morning, January 23, in the Engineering Societies Auditorium, New York, at a general session of the Winter Convention of the A.I.E.E.

The Edison Medal was founded by associates and friends of Thomas A. Edison, and is awarded annually for "meritorious achievement in electrical science, electrical engineering, or the electrical arts" by a committee composed of 24 members of the Institute.

Let ONE man take care of your COAL STORAGE PROBLEMS

If you have a man power shortage, let *one* man be responsible for storing and reclaiming coal — safely — rapidly—economically—with a Sauerman Scraper System.

Sauerman Scraper System, with 8 cu. yd. Crescent scraper operating on 450 ft. radius, handles 200,000-ton stockpile for 140,000 KWH station.

Consider these advantages:

1. **Maximum tonnage stored on all available space.**
2. **Operation is smooth and rapid.**
3. **Costs only a few cents per ton of coal moved into and out of storage pile.**
4. **Handles coal cleanly.**
5. **Stocks in compact layers — no air pockets to promote spontaneous combustion.**
6. **One man operates with one set of automatic controls.**
7. **Low original cost to install.**
8. **Simple and economical to maintain.**

The complete Sauerman Catalog is yours for the asking.

SAUERMAN BROS., Inc.
550 S. CLINTON ST., CHICAGO 7, ILL.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Handbook of Water Conditioning

An up-to-date text for study, reading or reference covering industrial water conditioning in all its phases. The book, compiled by W. H. and L. D. Betz, well-known Philadelphia chemical engineers and water consultants, contains 54 chapters and is divided into two sections. The first section entitled "Water Treatment" contains detailed discussions of the chemical and mechanical processes available for the treatment of water for industrial use, covering such subjects as coagulation, filtration, lime-soda softening, anion exchange, silica removal, boiler scale formation, embrittlement, slime and algae control, etc. The second section entitled "Water Analyses" deals with the impurities in water, how they originate, how they can be removed and methods of analyses suitable for plant control. Price $1.00 per copy, postage prepaid.

Chemistry of Coal Utilization

This is in two volumes containing about 1850 pages and was sponsored by a special committee of the Division of Chemistry and Chemical Technology of the National Research Council. This committee, headed by Dr. H. H. Lowry, of Carnegie Institute of Technology, consisted of forty members representing various research institutes and commercial organizations interested in coal. It arranged the subject matter into forty chapters, each dealing with one phase of subject, and preparation of the text was assigned to twenty-nine authors, selected because of their training and experience. These authors reviewed some 15,000 pages of literature on the subject, published in ten languages. Wherever possible, digests of the original articles are incorporated and the text is well supplied with references to the original publications.

In the first chapter, the study of the origin of coal is based on microscopic study of the substance and the structure of coal. This traces backwards the present coal substances through the transformation processes to the original plant substances. In the second chapter are discussed the various classifications of coals. However, much depends on point of view, classification that satisfies the students with the microscope may not suit men interested in steaming coals.

The third chapter, "Coal Petrography," is closely related to that of the first chapter on origin of coal. Coal petrography is a detailed microscopic study of the different parts of the coal substance and how these parts are related to the different parts of the plants from which the coal was derived. The study also traces types of coal to the original types of plant.

The fourth chapter on "Calorific Value of Coal" gives the story of the development of coal calorimeter and its manipulation.

The fifth chapter deals with hardness, strength and the grindability of coal and describes the different laboratory methods of determining these properties.

Chapter 6 gives the method of determining the plastic, the agglutinating, agglomerating, swelling properties of coals and what relation such determination may have to the caking of coal in furnaces and the production of coke in coke ovens.

Chapter 7 defines the physical properties of coal and describes the methods of determining them.

Chapters 8, "Chemical Constitution of Coal, as Determined by the Halogenation Reaction"; 9, "Chemical Constitution of Coal as Determined by Oxidation Reactions"; 10, "Chemical Constitution of Coal as Determined by Reduction Reactions"; and 11, "Chemical Constitution of Coal as Determined by Hydrolitic Reactions" deal with experimental studies to determine the structure or form of the coal molecules as they exist before any changes occur.

Chapter 12, "Forms of Sulphur in Coal," discusses the three forms, namely, the organic, the pyritic and the sulphate forms, and how these forms of sulphur affect the value of the coal.

Chapter 13, "The Occurrence of Nitrogen in Coal," deals largely with the origin of nitrogen in coal and the quantity occurring in various coal ranks.

Chapter 14, "Composition and Origin of the Mineral Matter in Coal," tells what these minerals are, and how they got into the coal.

Chapter 15, "The Fusion, Flow, and Clinkering of Coal Ash," discusses the fusibility of coal ash, how it is measured, how it is affected by the ash composition and its effect on clinkering and other behavior in boiler furnaces.

Chapter 16, "The Cleaning of Coal," describes different methods of cleaning coal and their effectiveness with different sizes.

Chapter 17, "Condition of Water in Coal," brings up the question of what part of the water in coal is moisture and what part is water of composition. A standard method of moisture determination makes results comparable but not necessarily correct.

Chapter 18, "Changes in Coal During Storage," is a discussion of changes or deterioration of coal during storage, and tendency to spontaneous combustion.

Chapter 19, "The Action of Solvent on Coal," is related with its contents to Chapters 8, 9, 10 and 11, and gives the results of experiments with a large variety of solvents.

Chapter 20, "Vacuum Distillation of Coal," discusses the results of experiments of coal distillation under reduced pressure. The results indicate that the quantity and the kind of products are not greatly different from those obtained under atmospheric pressure.

Chapter 21, "Industrial Coal Carbonization," compares the beehive with the by-product coking of coal, and describes the apparatus and its operation in various designs of plants.

Chapter 22, "Dependence of Yield of Products on Temperature and Rate of Heating," presents operating data in support of the importance of temperature and rate of heating.

Chapter 23, "Preparation of Coal for Carbonization," considers the preheating of the coal and oxidation above normal atmospheric temperature. Experimental results show that the quantity and quality of the products can be varied by careful control of preoxidation.

Chapter 24, "The Physical Properties and Reactivity of Coke," emphasizes the desirability of laboratory tests of such physical properties of coke that would indicate truthfully the value of the coke for various uses, and describes some of the methods that have been tried.

Volume 2

Chapter 25, "Gas from Coal Carbonization—Preparation and Properties," gives the analyses, specific gravity, heating value of the gas; also a short discussion of individual constituents of the gas.

Chapter 26, "Removal of Sulphur Compounds from Coal Gas," describes the various sulphur compounds and the objections to their presence in coal gas, and describes commercial methods and apparatus for its removal.

Chapter 27, "Recovery of Ammonia, Cyanogen, Pyridine and Other Nitrogenous Compounds from Industrial Gas," is a comprehensive discussion of the nitrogen compounds in coal gas, their yield from different coals, and including description of the methods and apparatus for commercial recovery.

Chapter 28, "Light Oils from Coke Oven Gas," gives tables of constituents and their physical properties, description of methods and apparatus for recovery and commercial plants for refining crude oil from coal gas.

Chapter 29, "Removal of Miscellaneous Constituents from Coal Gas," discusses the removal of other constituents not covered in Chapters 26 to 28 because their removal is not done generally. Among these constituents are indene, styrene, ethylene, carbon monoxide and hydrogen.

Chapter 30, "Utilization of Coal Gas," discusses the fundamentals of combustion of coal gas, and describes the action of the bunsen burner and burners for home gas-burning appliances. It also discusses industrial application of coal gas for controlling furnace atmospheres.

Chapter 31, "The Chemical Nature of Coal Tar," is a thorough discussion of the nature and yield of tar from different kinds of coals under different coking conditions. It contains many tables giving the physical properties of the different constituents of the tar.

Chapter 32, "Ammoniacal Liquor," deals with the disposal of ammoniacal liquor produced in coke and gas plants.

Although ammonia is valuable, its production from these liquors is too costly compared to the cost by nitrogen fixation method. At present ammoniacal liquor is more of a problem of disposal than utilization.

Chapter 33, "Combustion in Fuel Beds," gives a description of commercial stokers and their operation, with a discussion of the process of combustion.

Chapter 34, "The Combustion of Pulverized Coal," presents a brief history of the development of burning coal in pulverized form and discusses some typical installations of pulverized coal fired boilers.

Chapter 35, "Direct Generation of Electricity from Coal and Gas (Fuel Cells)," is a theoretical discussion of the possibilities of generating electricity by consuming commercial fuel such as coal in cells. Commercial success of such a process is not encouraging.

Chapter 36, "Producers and Producer Gas," is a thorough discussion of the theory of gas producer operation supported by experimental results.

Chapter 37, "Water Gas," discusses the process of making blue gas and carbureted blue gas from coke anthracite and bituminous coals.

Chapter 38, "Hydrogenation of Coal and Tar," deals with the process of combining more hydrogen with the coal substance and changing a large part of it into liquid fuel. Flow diagrams and description of commercial plants are included.

Chapter 39, "Synthesis of Hydrocarbons from Water Gas," deals with producing liquid fuel from CO and H_2 obtainable from water gas, coke oven gas and even blast furnace gas by the use of catalyst. Describes the development of these processes and the growth of large-scale plants in Germany during the last eight years.

Chapter 40, "Methanol Synthesis from Water Gas," deals with the production of alcohol from CO and H_2 by the use of proper catalysts, of which there are a great many in use. Considerable quantity of methyl-alcohol is produced annually in this country.

The two volumes make an excellent reference work for those who are engaged in coal research, and particularly those who are planning coal research experiments. A study of the chapters related to the particular part of the broad subject of coal, which they wish to investigate, may save much time and expense by learning first what has been done along that line. The first volume deals mostly with laboratory investigations of the origin of coal, the chemical and physical properties of the various classes of coal, and how these properties may bear on commercial processes of coal utilization. The second volume contains largely the description of types of the commercial apparatus and their operation.

The price of the two volumes is $20.

According to P. Dunsheath, president of the Institution of Electrical Engineers (Great Britain), new generating capacity added to 73 power stations from January 1, 1939 to December 31, 1944, amounted to 3,896,000 kw along with boiler capacity of more than 49 million pounds of steam per hour. Total output in the latter year was 45 per cent above that of the former.

NEW EQUIPMENT

Electrical Heat Exchanger

The Brown Fintube Company has just introduced a new heat exchanger that employs electrical resistors as the heat source. The electrical resistors are encased inside a length of standard Brownweld fintube. Current density of typical resistors now in use is 4 kw per linear foot of fintube. The rating on the outside surface (due to the large ratio of exterior to interior area of the fintube) is only about 8 watts per square inch, thus avoiding high skin temperatures that might cause carbonization of heat sensitive materials.

Brownweld fintubes fitted with electrical resistors are applicable in double tube, bayonet, vertical immersion or other types of heat exchangers, and permit great flexibility as to the size and capacity of the equipment.

Brown Fintube electrical resistor heat exchangers are ideally employed when steam is not available, when it is desired to eliminate the auxiliary piping required when steam is used, or to heat the fluid to higher temperatures than can be reached with steam.

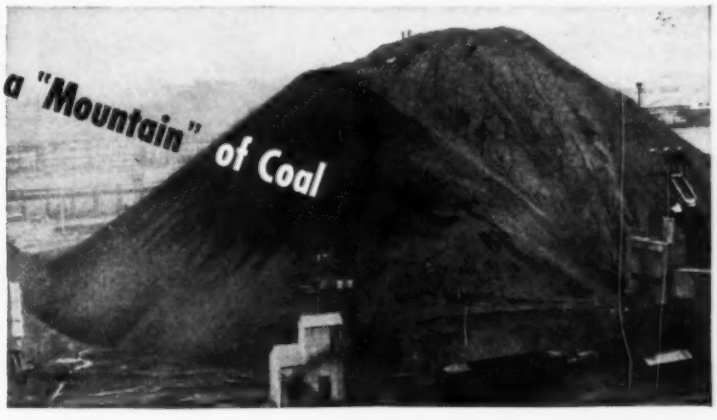
Combustibles Recorder-Controller

A new automatic analyzer and recorder for indicating, recording and controlling the combustibles content of a gaseous mixture, has been developed by the Bailey Meter Company. The analyzer and recorder provide a continuous graphic analysis almost instantly, and they are said to be responsive to changes of 0.05 per cent combustibles. Sustained accuracy is said to be within 0.25 per cent.

A continuous gas sample is mixed with compressed air and burned on a catalyst-filament which reaches a temperature proportional to the combustibles content. Since the filament resistance is a function of temperature, a simple resistance bridge connected to a null-balance electronic recorder completes the installation. It may be calibrated in per cent combustibles, mixture ratio, or other desired terms.

Pneumatic control or electric alarm contacts may be provided on both one and two-pen recorders. A two-pen recorder utilizes separate analyzers so that the speed is not impaired by switching, and the two records are independent of each other.

Handling a "Mountain" of Coal



• One industrial plant increased its coal-pile depth from 48 to 116 feet, and boosted pile capacity from 39,000 to 150,000 tons in limited space. Although probably the highest coal pile in the world, fire hazard is actually reduced because pressure within the pile minimizes the air content.

To accomplish this, Beaumont engineers installed an aerial bridle system suspended from three 85′ towers with the tail block position remotely controlled from the operator's station on the previously installed Beaumont cable drag scraper system.

Although your coal storage problem may not be as difficult as this one, chances are that Beaumont's 40 years' experience can save you time, trouble and money in finding the solution. Write outlining your requirements.

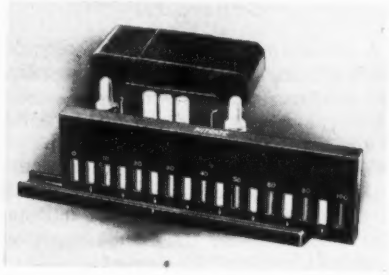
BEAUMONT BIRCH COMPANY

1506 RACE STREET PHILADELPHIA, PA.

DESIGNERS • MANUFACTURERS • ERECTORS OF COAL AND ASH HANDLING SYSTEMS

Nitrate Comparator

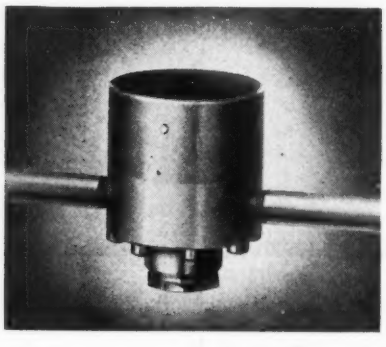
W. H. & L. D. Betz and W. A. Taylor & Company have jointly developed a simple accurate test for the nitrate ion in boiler water. The test procedure was established in the laboratory of W. H. & L. D. Betz and the equipment designed by W. A. Taylor & Co.



The Taylor-Betz Nitrate Comparator finds particular application in routine plant control of the Nitrate/Hydroxide ratio in boiler waters for the prevention of embrittlement. The equipment consists of a comparator base and slide covering the range 0 to 100 ppm nitrate in nine gradations. An initial supply of reagents is furnished with the comparator. The accuracy of the method is not affected by ions normally present in boiler water.

Pressure Reducing Regulator

The new small and compact Grove Mity-Mite Regulator weighing less than 2 lb and measuring roughly $2^3/_4 \times 3^1/_4$ in. is suitable for handling initial pressures up to 3500 lb with adjustable control range from 5 to 1500 lb. Special models can be supplied for higher initial pressures ranging up to a maximum of 5000 lb. Al-

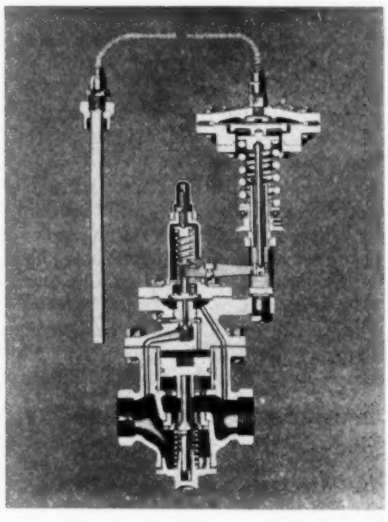


though primarily designed for air and gases, including hydrogen, nitrogen, oxygen, etc., this diminutive yet powerful unit can also be furnished for liquid service. Its rugged strength is attributed to the homogenous structure of Duraluminum from which it is made. Unique valve and seat construction was especially engineered for positive dead-end shut-off. It is instantaneous in its operation. Available for $^1/_8$- and $^1/_4$-in. pipe size this tiny unit was originally developed and proved in wartime service, where it was extensively employed in controlling the actuating medium on rockets and pack type flame throwers. Full details, contained in Bulletin 940, are available on request.

Temperature Regulator

The Leslie Company has announced a new self-contained internal pilot, piston-operated Temperature Regulator for steam service. It features Duo-Matic Control whereby temperature regulation and pressure control are obtained simultaneously with a single regulator. It is equipped with metal diaphragms and has no bellows or packing glands. All wearing parts of stainless steel and vital parts are hardened to 500 Brinell. The new regulator has a rugged thermostatic element with 100-deg F adjustable range.

The vapor-filled thermostatic element, acting through the upper diaphragm and lever, opposes pressure limit spring and determines the steam pressure delivered by regulator to heat exchanger. Manual compression of the limit spring determines



maximum outlet pressure and opens controlling valve admitting high pressure steam from inlet body port to top of piston which opens main valve. The outlet steam pressure acting under steam diaphragm balances compression of limit spring, throttling control valve and limiting the maximum outlet pressure.

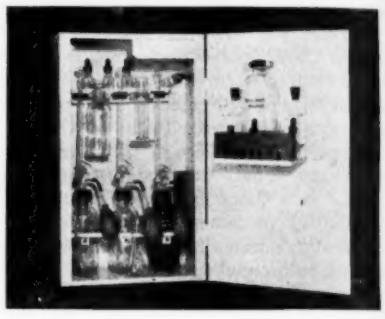
The temperature at which the vapor pressure starts to oppose the limit spring and decrease outlet steam pressure is set on the adjusting spring. This spring opposes the vapor pressure through the large upper diaphragm and, by means of this spring, the temperature at which all steam to heater will be shut off can be accurately set.

Maintenance Refractory

Zircoat-M is a zirconium silicate base refractory developed by Basic Refractories, Inc., which upon application with a spray gun sets up rapidly to form a hard, dense working surface that will withstand high furnace operating temperatures and unusual furnace conditions. It is a fine-grained material shipped dry in 100-lb bags. Zircoat-M is mixed with water for spraying and has been extensively used as a protective coating on silicon carbide, fireclay, sillimanite, mullite, silica and other acid type refractories.

Water Analysis

A compact, economical but completely equipped "Testmaster Junior" for water analysis has been developed by TruTest Laboratories, Inc. This new cabinet is in effect a simplification of "Testmaster" itself, retaining the parent model's com-



pactness and flexibility as well as its major functions. For any plant where hardness, alkalinity to P & M and chloride determinations are adequate for dependable water control, "Testmaster Junior" contains in one practically arranged cabinet complete apparatus and the reagents for making these tests. Moreover, these tests can be made accurately by any intelligent layman after a very brief period of instruction.

Where it is desired to incorporate wide range pH determinations and phosphate determinations, "Testmaster Junior" is so designed that the same cabinet, without modifications, will accommodate the TruTest Phosphate Tray and the TruTest pH Test Unit. Thus, "Testmaster Junior" is potentially available for all normal water control tests except dissolved oxygen in a completely portable and equipped unit.

Manufacturers' Personnel

C. J. Bickler has recently been appointed manager of sales of Globe Steel Tubes Company's Los Angeles Office. For the past three years he has served as assistant to the vice president in charge of sales at the home office in Milwaukee.

B. H. Van Dyke has been appointed manager of the New Products Department of the Elliott Company, Jeannette, Pa., having previously served as assistant to the director of research and development.

Yarnall-Waring Company recently announced the following personnel changes: **Joseph Kildare** as sales manager, and the transfer of **Frank W. Miller** to the Chicago Office as sales engineer; **Charles H. Grosjean** from sales engineer in the New York Office to Detroit, replacing **C. N. Maxfield,** who has been appointed California district manager; and two new men, **Jackson Kemper** at the New York Office and **Jack Schuyler** at the Los Angeles Office.

De Laval Steam Turbine Company has appointed **H. H.Barrows** and his organization of the Industrial Equipment Company, Detroit, as sales representative for the Lower Michigan Peninsula, handling the IMO Pump and Worm Gear Divisions.